PRODUCTIVITY OF CROSSBRED EWES UNDER ACCELERATED LAMBING AND ACCURACY OF ESTIMATING LIFETIME PRODUCTIVITY

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CHAPTER I

INTRODUCTION

Lamb meat is one of the important sources of animal protein needed to feed the world's population. In recent years, sheepmen in the United States have become increasingly interested in improving the efficiency of lamb meat production. In Oklahoma, accelerated lambing programs--an earlier study of lambing twice-yearly (1964-1968) and a current program of lambing three times in two years (1971-1979)--have been tested to determine their applicability for lamb meat production. According to Large (1970), an increase in the frequency of lambing would increase the biological efficiency of meat production from sheep.

In a review article (Turner, 1969) it was shown that improvement of the reproductive rate of the ewe may be brought about by direct selection; although most of the reports that she cited indicated a fairly low heritability, ranging from 0 to .35 (average .15) for this trait. However, a more rapid change in reproductive rate in a flock may be obtained if crossbreeding with a breed of high natural prolificacy is employed. Crossbreeding of the Finnsheep with a number of other breeds has been reviewed by Bradford (1972). His results have consistently shown that litter size is inherited in an approximately additive fashion, with litter size in the crossbred ewe being intermediate between that of the Finnsheep and the other parent.

The aims for increasing the reproductive rate of commercial ewe flocks are therefore twofold: 1) the infusion of germ plasm of more prolific breeds in the flocks and 2) the adoption of some type of accelerated lambing program to shorten the interval between lambings. The Finnsheep, an "exotic" prolific breed from Finland, in crosses with Western ewes have been used in accelerated lambing programs to achieve these aims in Oklahoma. The productivity of Dorset x Rambouillet crosses, which, of course, is known under Oklahoma conditions in twice-yearly lambings, is evaluated alongside the Finnsheep crosses. The Dorset's extended breeding season and the Rambouillet's ability to adapt to severe conditions are some desirable qualities in this program.

The objectives in this study were: 1) to compare the fertility and prolificacy for these crossbred ewes in three breeding seasons--winter, fall and late-spring under accelerated lambing and also compare purebred and crossbred rams of Hampshire and Suffolk breeding when they breed these ewes in January-February, September-October and May-June; 2) to evaluate the interval from lambing in one season to conception in the next season on all ewes that lambed in successive seasons, when ewes are lambed every eight months; and 3) to estimate repeatabilities and to use the estimates as an aid in predicting the lifetime performance of these crossbred ewes.

CHAPTER II

LITERATURE REVIEW

Productivity of Ewes Under Accelerated Lambing

Under an accelerated lambing program, ewes may be lambed either twice yearly or three times in two years. Under the former program of lambing every six-months or 182 days, with a gestation period of 147 days, this will leave an ewe about 35 days within which to recover and be bred again for the next lambing. On the other hand, ewes lambed under an eight-month or 242-day program, would have about 95 days to recover before the next breeding. The time of year during which ewes are lambed may therefore be an important factor in accelerated lambing programs; because ewes usually enter into post partum anestrus after lambing and in some cases seasonal anestrus depending on which season of the year the lambing occurred. Factors such as light (Sykes and Cole, 1944; Yeates 1947) and temperature (Dutt, 1953) which are part of the component of the season of the year, may play an important part in accelerated lambing programs.

As an extensive example demonstrating the effects of the time of the year in which ewes are lambed (Shelton and Morrow, 1965) in Texas, found differences during the year in ovulation and lambing rates that were related to changes in photoperiod and also to temperature. A total of 539 aged Rambouillet ewes in two replicates during a two-year period were involved and a highly significant difference in ovulation rate at different seasons, with a low in March and a high in September was observed. In September 72.5% of the ewes exhibited multiple ovulations compared with 15% in March. June and December mating periods were intermediate. They also found that the largest number of lambs born resulted from the December mating. Generally the number of lambs born steadily increased as the season advanced from March to December. The highest ovulation rate occurred at the September mating, while the highest lambing rate followed the December mating. They suggested that the length of the photoperiod was the major factor affecting the occurrence of estrus and ovulation rate, but the lambing results, particularly at the June and September mating periods, were substantially modified by high environmental temperature.

The aim under accelerated lambing programs, has therefore been to use prolific breeds and/or breeds with extended breeding season in order to shorten the interval between lambings.

During a three-year period in France, Mauléon and Dauzier (1965) recorded the post-partum intervals to estrus following 306 lambings scattered throughout the year in Ille-de France ewes (Table I). They concluded that when ewes lambed early in the year, seasonal anestrus at first markedly prolonged the post-partum interval, but this effect was greatly reduced as the year advanced. Thus, in ewes which lambed between late winter and late summer, the resumption of cyclic activity was slow due to the relative ineffectiveness of the seasonal stimuli. On the other hand, in ewes which lambed in autumn or early winter (September-November) the seasonal anestrus did not prolong the post-partum interval and the ewes returned to estrus within two months of lambing, although in some cases only a single instance of heat was

TABLE I

DISTRIBUTION OF POST-PARTUM INTERVAL TO ESTRUS IN ILLE-de FRANCE EWES FOLLOWING 306 LAMBINGS SCATTERED THROUGHOUT THE YEAR

Month of Parturition	n	Mean Post-Partum Interval to Estrus (Days)
December	12	237.7
January	6	193.3
February	17	162.8
March	30	147.3
April	31	123.3
May	8	112.9
June	15	82.1
July	21	71.1
August	23	63.8
September	58	51.4
October	46	55.0
November	39	48.2

Data recorded between 1956 and 1959. Intact, aproned rams used for testing once daily.

Source: Mauléon and Dauzier (Cited by Hunter, 1968), p. 347.

recorded before anestrus set in.

Whiteman et al. (1972) observed post partum mating performance of Dorset, Rambouillet and Dorset x Rambouillet ewes in a twice yearly lambing program in Oklahoma during four fall seasons (1964-1967) and four spring seasons (1965-1968). Of 537 ewes that could have lambed during the fall only 188 (35%) lambed; and in the spring, out of 591 ewes, 495 (84%) lambed. Ewes that lambed during the fall more often resumed their cycling behaviour while nursing their lambs and conceived. Of all the ewes that lambed during the fall, 71 percent conceived and lambed again the following spring. The average interval between fall lambing and the next conception was 44 days. For ewes that lambed during the spring, a greater proportion did not resume cycling quickly. Only 23 percent of the spring lambing ewes remated and conceived to lamb the next fall. The average interval between spring lambing and the next conception was 66 days.

Walton and Robertson (1974), in a twice yearly lambing of Finnsheep in Canada confirmed Whiteman and others' results. It was reported that the conception rate at two spring exposures was lower than at the fall mating; which suggested that by the middle of March some of the ewes were in the anestrus state.

Hunter (1968) has presented two amply reviewed articles in Animal Breeding Abstracts, under the general topic of "Increasing the Frequency of Pregnancy in Sheep". In his first review article where he presents some factors affecting rebreeding during the post-partum period, he reported:

> it seems probable that ewes with inherently longer breeding season will generally return to estrus sooner after lambing than short-season breeders, but that the return will nevertheless be influenced by the date of lambing. Furthermore,

> there seems little doubt that the length of the post-partum anestrous period is likely to be shortened in ewes which lamb nearer the start or peak of their breeding season, than in those which lamb later in the season.

Hunter's review articles included data from many parts of the world. He, therefore, made it a point, where necessary, to indicate the locality from which different reports emanated; as well as the month of lambing of the ewes concerned.

Thomas and Whiteman (1979) in two papers, presented the productivity of spring lambing ewes and fall lambing ewes. Their results are presented in Table II. Their data suggested that the Finnsheep breed is less able to conceive to May and June mating (to lamb in the fall) than is the Rambouillet breed, and that an increase of Finnsheep genes at the expense of Rambouillet genes resulted in a decreased percent ewes lambing. Their results however showed a sizable increase in prolificacy for 1/4Finnsheep, both in the fall of 1974 (.20, $P < .10$) and 1975 (.22, $P < .05$); while the 1/4Finnsheep and 1/4Dorset effects resulted in positive but nonsignificant increases in prolificacy in both 1973 and 1974 for spring lambings. At the time of writing, there were virtually no literature reports concerning the performance of ewes lambing in the summer, precisely, in June-July.

General ideas of some of the effects of the time of year or season within which ewes are lambed have been presented above. The rest of the review concerning the productivity of ewes under accelerated lambing will be pursued in three parts: i) number of ewes lambing per total ewes exposed to the ram; ii) number of lambs born per ewe lambing; iii) number of lambs born per ewe exposed to the ram. Under accelerated lambing also, a section will be presented on the intervals between lambings. Lastly, a review concerning published estimates of

TABLE II

LAMBING PERFORMANCE OF SPRING- AND FALL-LAMBING EWES AND THEIR BREEDING PERIODS UNDER OKLAHOMA CONDITIONS

Age Year	Ewe Breeding[a]	Breeding Date	No. of Ewes Exposed	Fertility %	Prolificacy
		Spring Lambing Ewes			
1973	1/2D1/2R	Sept. 15-Nov. 6	50	89.4 ± 5.26	1.53 ± .094
	1/4D3/4R	1972	52	83.1 ± 5.88	1.54 ± .098
	1/4F1/2D1/4R		41	82.2 ± 5.82	1.72 ± .110
	1/4F1/4D1/2R		47	86.7 ± 5.58	1.53 ± .101
1974	1/2D1/2R	Aug. 23-Oct. 19	25	96.0 ± 8.85	1.66 ± .164
	1/4D3/4R	1973	27	77.5 ± 7.97	1.51 ± .161
	1/4F1/2D1/4R		21	95.4 ± 9.87	1.62 ± .184
	1/4F1/4D1/2R		21	85.0 ± 8.35	1.71 ± .164
		Fall Lambing Ewes			
1974	1/2D1/2R	May 15-July 2	54	79.2 ± 5.81	1.51 ± .087
	1/4D3/4R	1974	57	70.6 ± 6.01	1.37 ± .094
	1/4F1/2D1/4R		45	61.9 ± 6.80	1.73 ± .117
	1/4F1/4D1/2R		52	59.7 ± 6.35	1.56 ± .111
1975	1/2D1/2R	May 15-July 3	53	85.6 ± 6.62	1.45 ± .086
	1/4D3/4R	1975	57	87.1 ± 6.47	1.27 ± .086
	1/4F1/2D1/4R		43	64.3 ± 8.26	1.48 ± .130
	1/4F1/4D1/2R		51	58.7 ± 6.55	1.67 ± .110

[a]F = Finnsheep, D = Dorset, R = Rambouillet

Source: Thomas and Whiteman (1979): J. Anim. Sci. 48: 256-264.

repeatabilities of number of lambs born and also estimates of subsequent number of lambs produced based on first or second lambing performances will be given.

Number of Ewes Lambing Per Ewes Exposed to the Ram

This characteristic will tend to vary with time of year, with breed of ewe, and with age of the ewe. In terms of lifetime productivity of the ewe, the age at which she reaches sexual maturity and begins reproduction may have a considerable effect.

Sidwell and Miller (1971) studying the reproductive efficiency in some pure- and crossbred ewes, reported that season of lambing had an important effect on fertility. Laster et al. (1972) indicated that for a total of 565 ewe lambs of 19 breed groups including Finnsheep and Rambouillet-sired crosses small increases in the age of the ewe lamb at breeding gave highly significant increases in the number of ewes lambing. The mean age of these ewe lambs at lambing was 379.5 ± 3.2 days and they were exposed to fertile rams from November 9th to December 14th. These authors reported that the condition and body weight of the ewe lambs at the start of the breeding did not appear to affect the number of ewes lambing per ewe exposed.

Over a seven-year period in the state of Kansas, 900 matings involving 762 ewes produced 994 lambs (Jayarama-Krishna et al., 1978). Ewes were Columbias, Rambouillets and black-faced crossbreds (Suffolk x Western range); sires were Suffolks, Hampshires, Shropshires and Southdowns. The ewes were lambed once a year, from December to April. The proportion of ewes lambing averaged 89.3% for Rambouillets vs 82.5% for

Columbias and 83.1% for black-faced crossbreds. The percentage of ewes lambing averaged 90.8% and 89.8% from matings with Suffolk and Hampshire rams, respectively, vs 86.5% for Shropshire and 72.8% for Southdown rams.

The performance of Finn-Dorset sheep allowed to mate four times in two years was reported by Land and McClelland (1971). There were 103 ewes of approximately one and two years old. The summer matings during the two years they considered took place between July 27 and September 14, 1967 and between August 23 and September 27, in 1968. During these summer mating periods, all non-pregnant, non-lactating ewes were teased daily with vasectomized rams, and those in estrus mated to fertile Finn-Dorset rams at the time of detection, and 9 or 17 hours later. The spring mating took place between March 20 and April 24, in 1968 and between March 1 and April 4 in 1969. They (Land and McClelland, 1971) assessed the effects of a short inter-mating period in terms of the proportion of animals pregnant or non-pregnant following a particular mating period which were again pregnant at the next. The number of lambs born to ewes which were lambing for the second successive time compared with contemporaries which did not lamb at the previous lambing were also assessed. They found that the occurrence of a particular pregnancy had very little effect on the number of lambs born to a mating soon afterwards (reduced by 5%) but that it had a very large effect on the proportion of ewes fertilized. Whereas 93% of ewes which had not lambed immediately beforehand became pregnant, only 32% of those which had lambed did so ($P < .001$).

Some literature values for fertility obtained under accelerated lambing have been presented in Table III. These values range from 26

TABLE III

LITERATURE SOURCES AND ESTIMATES OF NUMBER OF EWES LAMBING PER TOTAL EWES EXPOSED TO THE RAM UNDER SOME FORM OF AN ACCELERATED LAMBING PROGRAM

Breed of Ewe	Method	Season Breed	Number of Ewes	Fertility Value (%)	Reference
Finns	First lambed at 376±29.9 days	Exposed to rams throughout the year (1967) except from May-July	95	97.0	Goot and Maijala (1977) in Finland
	First lambed at 329±50.4 days		20	75.0	
Galway	Performance at one year of age	(not stated)	120	27.1	Quirke (1978) in Ireland
1/4 Finn x 3/4 Galway			90	29.5	
Finns			33	45.2	
1/2 Dorset x 1/2 Ramb.	Performance at one year of age	Oct. 18-Dec. 22, 1972	51	60.2	Thomas and Whiteman (1979) in U.S.A.
1/4 Dorset x 3/4 Ramb.			52	52.9	
1/4 Finn x 1/2 Dorset x 1/4 Ramb.			44	84.0	
1/4 Finn x 1/4 Dorset x 1/2 Ramb.			51	77.1	
Precose	Twice-yearly	After normal season lambing, ewes were put to the rams within 10 to 20 days after parturition	80	71.4	[h]Kirillov (1944) in Russia
Dorset	Twice yearly over 4-5 years	April-June	537	35 60[a]	Whiteman et al. (1972) in U.S.A.
Rambouillet		Oct.-Dec.	591	84	
Dorset x Ramb.					
Finns	Twice-yearly. 5 consecutive lambings	Jan.-April Aug.-Nov.	172	84.9	Walton and Robertson (1974) in Canada
Spanca	Twice yearly. 6 consecutive periods	Normal breeding season in August. 2nd, 4th and 6th mating periods were out of season	164 157 (2nd) 130 135 (4th) 107 103 (6th)	97.5 38.2 98.6 69.5[a] 44.4 84.1 54.4	Petcu et al. (1977) in Rumania
Western Ewes	Mated for near maximum frequency of lambing over 4 consecutive periods	Aug.-Sept., 1961	26	96.0	Copenhaver and Carter (1964) in U.S.A.
		March-April, 1962	26	95.0	
		Oct.-Nov., 1962	26	100.0	
1/2 Finn x 1/2 Ramb.	3 times in 2 years (1 cycle)	March-Apr 1, 1973 clean up breeding in Sept. 1973. Regular breeding in Nov. 1973	30	80.6	Carter and Copenhaver (1974) in U.S.A.
1/4 Finn x 3/4 Ramb.			42	69.2	
Finn x Dorset	3 times in 2 years. Over 5 consecutive lambings.	Jan.-Feb.	48	87.8	[1,h]Robinson and Orskov (1975)
Finn x Dorset	3 matings in 2 years (1 cycle)	Normal mating in Nov. 1973 - Synchronized mating in Aug. 1974 and also in Feb. 1975	51 51 51	80.0 82.0 81[a] 73.0	[h]Speedy and Fitz-Simons (1977) in England
BD x SB*			50 50 50	96.0 56.0 60[a] 20.0	

*BD = Border Leicester
SB = Scottish Blackface and Grayface
a = Average
h = Hormone Therapy
l = Artificially controlled light treatment

percent (Speedy and FitzSimons, 1977) to 100 percent (Copenhaver and Carter, 1964). The seasons when the ewes were bred have also been indicated in the table. In some of the citations, the seasons when the ewes were bred were indicated but particular values were not given, only average values were given. In Carter and Copenhaver's (1974) study, they bred their ewes in March-April, 1973. Those that failed to lamb in September of that year were bred in September, that is, a clean up breeding. Those lambing in September had their lambs weaned at about five weeks of age and were rebred in November to lamb in April-May, 1974. Their breeding periods were therefore at variable intervals and not at approximately eight months intervals.

Robinson and Ørskov (1975) pointed out that a notable feature in the Finn-Dorset cross was their early puberty and high fertility when bred as ewe lambs. An extreme example of their precociousness, they pointed out, was the production of viable lambs at seven months and eighteen days of age without resort to hormone therapy. With regard to their fertility, 95 percent of spring born ewe lambs normally conceived to a naturally occurring estrus at seven to nine months of age and gave lambing percentages in the range of 150 to 180.

The first three references in Table III were to give an indication of the performance when some of the ewes were lambed as yearlings. Fertility values for ewes lambing as yearlings were generally lower than values for fertility reported for mature ewes. Values of fertility under twice-yearly lambing programs are presented after the report on yearling fertility. Also presented in Table III are values of ewe fertility under the system of lambing three times in two years.

A notable feature in Table III is that, irrespective of the breed of ewe used, fall lambing generally indicated the fertility to be low. Fertility values reported from spring lambings were high. Also low fertility values were reported when ewes were bred to lamb out of season. For example, the 2nd, 4th and 6th lambings reported by Petcu et al. (1977) in Spanca ewes were lower than values reported when these same ewes were lambed during their regular lambing seasons.

Number of Lambs Born Per Ewe Lambing

This trait is very much affected by a variety of factors, with probably age, breed of ewe and season of lambing being the major ones. Bradford (1972) reported means for different breeds of ewes ranging from very close to 1.0 to over 3.0. Within each breed there is considerable variation in litter size, according to the age of the female. Sidwell and Miller (1971) reported that age of dam had a significant effect only upon prolificacy and overall production. Their ewes were bred to lamb at one year of age and lambed three more times during the four years under the study (i.e. 1966-1969). All lambs were born during February and the first half of March.

Goot and Maijala (1977) in a twice-yearly lambing in Finnsheep in Finland, reported that the individual litter size was not affected by year, age of ewes, or lambing periods. For a total of 118 ewes used during 1968-72 period, litter size averaged 2.77 lambs born and 2.34 lambs alive at 14 days of age during January to May, and 2.50 lambs born and 2.31 lambs alive at 14 days of age during June to December. Land and McClelland (1971), on the performance of 113 F_1, F_2 and F_3, Finn-Dorset ewes under twice-a-year lambing system, reported that litter size was not affected very much by an ewe lambing six-months previously or lactating at the time of mating.

Maijala (1966) stated that maximum litter size for Finnsheep ewes at birth, two week and at weaning was achieved by six-year old ewes. Sidwell, Everson and Terrill (1962), working with a variety of purebreeds and their crosses in an eight-year study from 1952 through to 1959, concluded that the peak fertility and prolificacy were achieved at four years of age, with the most productive ages being four to seven years. Reeve and Robertson (1953) stated that there was generally an increase in prolificacy with the age of the ewe up to five to six years of age.

In an earlier study on the prolificacy of the Romanov sheep in Russia, Smirnov (1935) summarized data collected in a number of state or collective farms. From his summary, he indicated that prolificacy can be greatly increased by appropriate feeding, because he had observed that increased body weight of ewes was associated with a greater number of lambs per ewe. He also reported that prolificacy was dependent on age, younger and older ewes producing fewer lambs. Prolificacy, however, rises until the 5th lambing and then decreases slowly to the 10th.

Some reported estimates of litter size or prolificacy have been listed in Table IV. Again, the first three references are some indications of the prolificacy as yearlings. The listed values range from 2.1 (Robinson and Ørskov, 1975) to 4.72 (Eyal et al. 1973). The seasons in which the ewes were bred have been indicated in the table, where possible. Maijala and Kangasniemi (1972), on their experiences of out-of-season and twice-a-year lambings in Finnsheep, noted that the autumn lambings show somewhat lower values than the spring lambings.

TABLE IV

LITERATURE SOURCES AND ESTIMATES OF NUMBER OF LAMBS BORN PER EWE LAMBING UNDER SOME FORM OF AN ACCELERATED LAMBING PROGRAM

Breed	Method	Season Breed	Number of Ewes	Prolificacy Value	Reference
1/2 Finn x 1/2 Dorset	Performance at one year of age	March-April	26	1.96	Carter et al. (1975) in U.S.A.
1/4 Finn x 3/4 Dorset			20	1.55	
Dorset			9	1.22	
Galway	Performance at one year of age	(not stated)	120	1.12	Quirke (1978) in Ireland
1/4 Finn x 3/4 Galway			90	1.10	
Finns			30	1.21	
1/2 Dorset x 1/2 Ramb.	Performance at one year of age	Oct. 18-Dec. 22, 1972	51	1.11	Thomas and Whiteman (1979) in U.S.A.
1/4 Dorset x 3/4 Ramb.			52	1.05	
1/4 Finn x 1/2 Dorset x 1/4 Ramb.			44	1.16	
1/4 Finn x 1/4 Dorset x 1/2 Ramb.			51	1.18	
Finns	Twice-yearly. 4 consecutive periods	(see notes)	20 20 20 20	2.80 2.80 2.45 2.75	Maijala and Kangasniemi (1972) in Finland
Awassi	Twice yearly	(see notes)	19	2.89	Eyal et al. (1973) in Israel
Assaf	3 times in 2 years	(see notes)	57	4.72	Eyal et al. (1973) in Israel
1/2 Finn x 1/2 Ramb.	3 times in 2 years (1 cycle)	March-April, 1973. Clean up breeding in Sept. 1973.	30	3.1	Carter and Copenhaver (1974) in U.S.A.
1/4 Finn x 3/4 Ramb.		Regular breeding in Nov. 1973	42	2.3	
Finn x Dorset	3 times in 2 years. 5 consecutive periods	Jan.-Feb. May-June Aug.-Sept.	48	2.1	l,h Robinson and Ørskov (1975) in England
Finn x Dorset	3 times in 2 years (1 cycle)	Normal mating in Nov. 1973.	51	2.34	h Speedy and FitzSimons (1977) in England
BL x SB*		Synchronized mating in Aug. 1974 and also in Feb. 1975	50	2.16	

*BD = Border Leicester
SB = Scottish Blackface and Grayface
h = Hormone Therapy
l = Artificially controlled light treatment

They recommended lambings in February-March, in September-October and in April-May if lambing three times in two years is practiced instead of two times in a year.

Eyal et al. (1973), on lamb production in frequently lambing dairy sheep, planned on four 70-day mating periods per year with intervals of 20 days between them. These were followed by respective lambing periods. The breeding calendar was as seen in Table V.

TABLE V

BREEDING CALENDAR OF AWASSI AND ASSAF EWES IN ISRAEL IN 1970/71 AND 1971/72

Period	Mating	Lambing
1	June 1st - Aug. 10th	Nov. 1st - Jan. 10th
2	Sept. 1st - Nov. 10th	Feb. 1st - April 10th
3	Dec. 1st - Feb. 10th	May 1st - July 10th
4*	March 1st - May 10th	Aug. 1st - Oct. 10th

*March-May mating was induced with hormones.

Source: Eyal et al. (1973) Wld. Rev. Anim. Prod. 9(4)65.

Their aim was to combine concentrated lambing (which is necessary for efficient husbandry) with maximum opportunity for mating of ewes. They found that the September - November breeding period resulted in the highest prolificacy (values were not given). March-May breeding period resulted in the poorest prolificacy.

Table IV shows values of high prolificacy (2.1 to 4.72) for mature ewes on some form of accelerated lambing program (twice yearly lambing or lambing three times in two years). Low values of prolificacy (1.05 to 1.96) were reported for ewes lambing at one year of age. From the reports cited, the indications are that prolificacy appears to increase in the seasons where the largest number of lambs are born (i.e. February - March or spring lambing). Prolificacy also appears to increase with age to a point.

Number of Lambs Born Per Ewe Exposed to the Ram

The average number of lambs born per ewe exposed is a function of both fertility and lambing rate and is an overall measure of reproductive performance. Probably the most meaningful parameter by which to assess output in a flock would be the mean annual lamb production; and this, of course, is dependent on the number of lambs born per ewe exposed. An uneven distribution throughout the year in the number of ewes mated (Walton and Robertson, 1974) or a high replacement rate (Robertson and Ørskov, 1975) can influence the conclusions to be drawn. For the above reasons, total production from the original ewes in the flock, over a given period of time, is the most meaningful measure.

Laster, Glimp and Dickerson (1972), in factors affecting reproduction in ewe lambs, indicated that Finn-cross ewes had significantly more lambs born per ewe exposed than Rambouillet crosses (1.34 vs .75). For 19 breed groups represented, Rambouillet-cross and Finn-cross ewes produced more lambs per ewe exposed than any of the straightbreds. They also reported that a small increase in ewe age at breeding significantly increased the number of lambs per ewe exposed.

Estimates obtained per year for number of lambs born per ewe exposed under accelerated lambing have been shown in Table VI. Values range from .3 (Ducker and Bowman, 1972) to 4.03 (Goot and Maijala, 1977). Ducker and Bowman (1972) could only get 11 Kerry Hill ewes to lamb, producing 3, 5, 0 and 7 lambs at four lambing seasons in March-April, 1969, December-1969-January, 1970; September-October, 1970, and May, 1971. They chose Kerry Hill as an example of a breed with a short natural breeding season. Clun Forest and Dorset were the respective examples of breeds with medium and long natural breeding seasons.

From the literature reports on lambing two times in a year or lambing three times in two years, overall measure of reproductive efficiency appears to be high for breeds that are prolific (for example, Finns) and for breeds that are long season breeders (for example, Dorsets). Values reported for this trait was also high (3.5) for Finn x Dorset crosses. Ewes of Dorset x Rambouillet breeding have also shown a high reproductive efficiency. For the Dorset x Rambouillet ewes, values reported ranged from 1.81 to 2.07; and these values may depend on the seasons in which they were lambed.

Finn and Dorset ewes and their crosses with other breeds appear to have high reproductive efficiency when lambing in their normal lambing season. In Oklahoma, United States, and several other places (for example, Canada and England), the normal lambing season is in the spring (February-March). Fall lambing or out of season lambing appears to result in a low reproductive efficiency.

Rebreeding Intervals Under Accelerated Lambing

The gestation period in ewes has been reported to lie somewhere

TABLE VI

LITERATURE SOURCES AND ESTIMATES OF NUMBER OF LAMBS BORN PER EWE EXPOSED TO THE RAM UNDER SOME FORM OF AN ACCELERATED LAMBING PROGRAM

Breed	Method	Season Bred	Number of Ewes	Lambs Born/Ewe Exposed/Year	Reference
Dorset	Twice-yearly. Over 4-5 years	April-June	60	1.77	Whiteman et al. (1972) in the U.S.A.
Rambouillet		Oct.-Dec.	60	1.73	
Dorset x Ramb.			62	2.07	
Finns	Twice-yearly. 5 consecutive lambings	Jan.-April Aug.-Nov.	172	3.54	Walton and Robertson (1974) in Canada
Finns	Twice-yearly. 1½-5½ years	Ewes exposed to rams throughout the year, except in June and July	118	4.03	Goot and Maijala (1977) in Finland
Spanca	Twice-yearly. 6 consecuitve lambings	Normal breeding in August 2nd, 4th and 6th mating periods were out of season	136	1.62	Petcu et al. (1977) in Rumania
Clun Forest	4 times in 2½ years	Nov.-Dec., 1968	30	1.60	[1]Ducker and Bowman (1972)
Dorset		Aug.-Sept., 1970	33	2.10	
Kerry Hill		May-June, 1970	30	.30	
		January, 1971			
Dorset	3 times in 2 years (2 cycles)	March-April	40	1.67	Carter and Copenhaver (1973) in the U.S.A.
Rambouillet		Cleanup breeding in	40	1.47	
Dorset x Ramb.		September.	40	1.81	
Suffolk x Ramb.		Regular breeding in	40	1.80	
Suffolk x Ramb.	Kept indoors	November	27	1.54	
Suffolk x Ramb.	Kept on pasture		22	1.87	
Finn x Dorset	3 times in 2 years. Over 5 consecutive lambings	Jan.-Feb. May-June Aug.-Sept.	48	3,50	[1,h]Robinson and Orskov (1975) in England
Finn x Dorset	3 times in 2 years (1 cycle)	Normal mating in Nov. 1973. Synchronised mating in Aug. 1974 and also in Feb. 1975	51	2.13	[h]Speedy and Fitzsimons (1977) in England
BL x SB*			50	1.67	
Mutton Merino	3 times in 2 years (1 cycle)	October, 1974 May, 1975 February, 1976	66	1.71	Grant and Maude (1978)

*BD = Border Leicester
SB = Scottish Blackface and Grayface
h = Hormone Therapy
l = Artificially controlled light treatment

between 141 and 159 days (American Veterinary Association, 1945). As calculated earlier, ewes will have 35 days and 95 days to recover and be bred again, under two times a year and three times in two years lambing schedules, respectively, with an assumed gestation of 147 days.

Cole and Miller (1935), in an extensive study in California, estimated the period of anestrum in the non-pregnant mature ewe to be about seven to ten months long. "Sexual season," which they defined to be the interval between the first and last estrus of a series of estrous cycles, was estimated to be about 100 to 150 days in length. The sexual season in most breeds of ewes will be between August 1st and March 1st. They studied the reproductive organ changes in semi-poly-estrous ewes during the sexual season, anestrum and pregnancy. Vaginal smears during these periods were also studied and they induced estrus with hormones during anestrum. Data on the time of the first estrus of the sexual season collected from their breeding flocks are presented in Table VII. The records for the Hampshire and Rambouillet breeds were significant only in that they show the sexual season for these breeds to be earlier than for the other three breeds included. Probably some were in estrus previously before the rams were turned in. The first estrus of the sexual season occurred during the last part of August or during September in most of the mature ewes used in their study.

Hammond, Jr. (1944), on the breeding season of sheep, reported that the breeding season on the average extends from early October to late March and is fairly evenly spaced about the shortest day, over a period where the time from sunrise to sunset is 11½ hours or less. Recently, Lax et al. (1974) studied the breeding season of Texas Rambouillet, Montana Rambouillet, Wisconsin Hampshire, Beltsville

TABLE VII

TIME OF YEAR WHEN THE SEXUAL SEASON BEGINS IN FIVE BREEDS AND ONE BREED COMBINATION OF SHEEP IN CALIFORNIA

Breed	Number of Ewes Observed in Each Breed	Date on Which Rams Were Turned in With Ewes	Earliest Date of First Observed Estrus	Average Breeding Date
Hampshire	114	July 29	Aug. 1	Aug. 17
Shropshire	86	Aug. 1	Aug. 20	Sept. 1
Southdown	120	Aug. 1	Aug. 12	Sept. 10
Romney	44	Aug. 1	Sept. 1	Sept. 14
Rambouillet	90	July 1	July 6	July 18
Romney-Ramb.	284	July 15	July 30	Aug. 21

Source: Cole and Miller (1935) in Amer. J. Anat. 57:39.

Hampshire, Suffolk, Dorset, Targhee, and Columbia ewes. They divided the year into 26 periods of two-weeks for each ewe and in each period an ewe was classified as to whether or not she showed at least one estrus. They reported that the proportion of ewes showing estrus in a two-week period showed well defined seasonal trends but there was no significant difference between breeds. June and July had essentially zero estrous activity while less than 40% of the ewes in most breeds exhibited estrus during April, May and August. Each of the eight breed groups consisted of 27 ewes.

Land (1971) estimated the mean interval from lambing to first fertile estrus during November to December breeding to be 34.9 days in Finn-Dorsets. Whiteman et al. (1972) found the average interval to first mating in fall lambing Dorset and Rambouillet ewes and their crosses to be 32 days; and in spring lambing ewes of the same breeding to be 59 days. Walton and Robertson (1974), basing their calculation on a 145-day gestation period, found the average interval from lambing to conception to be 37 days or less in 46.2% of Finn ewes lambed twice yearly.

Carter and Copenhaver (1973) in Virginia, United States, reported on three separate five-year studies. In their first five year report, the ewes were under accelerated lambing and mated two times in a year to rams of Dorset, Hampshire and Suffolk breeding. They found the lambing intervals for Dorsets to be 288 days, Rambouillets 305 days, Dorset x Rambouillets, 242 days and Suffolk x Rambouillets 264 days. In a separate study over a five year period with ewes under accelerated lambing, Carter and Copenhaver (1973) found the lambing interval to be 272 days for Dorset and Hampshire sired lambs of 113 ewes when weaned, on the average, at an age of 38 days and a weight of 32 lb; with ewes being put to the rams on pasture immediately after weaning. Lambing interval was 349 days in 30 ewes whose lambs were weaned conventionally. In a third five-year experiment comparing the performance of 27 Suffolk x Rambouillet ewes housed indoors and 22 Suffolk x Rambouillet ewes kept on pasture, Carter and Copenhaver (1973) estimated the lambing interval to be 301 days and 250 days, respectively. In an earlier study, Copenhaver and Carter (1964) found the intervals between lambings to be 203 and 205 days in 26 crossbred Western ewes (Hampshire and Suffolk by range ewe crosses) when they were mated for near maximum frequency of lambing. Average lambing dates in those ewes were: January 31st, 1962; August 22nd, 1962; and March 11th, 1963.

Lambing to conception interval was estimated to be an average of 116.6 ± 64.3 days in a flock of 320 Finnish Landrace ewes that lambed consecutively in five-and-a-half year period in Finland (Goot and Maijala, 1977) with lambings scattered throughout the year. Ewes lambing in March had the longest and most variable intervals (CV = 58%) and those lambing in August and December had the shortest and least variable (CV = 24%). One hundred and twenty of the ewes were lambed twice a calendar year; their estimated lambing to conception interval was 71.7 ± 24.7 days. Maijala and Kangasniemi (1972) in their experiences of-out-of-season and twice-a-year lambings in Finnsheep in various parts of Finland found the lengths of the lambing intervals to be widely distributed. In one locality where the matings were controlled, most of the intervals were between 200 and 240 days. In another locality where the ram was running with the ewes continuously, they found half of the intervals exceeding 250 days. Lastly, they found 13 intervals below 200 days on farms with unintentional matings.

The mean conception-to-conception interval for consecutive lambings with a planned conception-to-conception interval of 8 months or less was found to be 189.3 for 75 Finnish Landrace ewes in Canada (Walton and Robertson 1974). For the 75 ewes, the authors estimated the parturition-to-conception interval to be 37 days or less in 46.2% of the ewes, and also a parturition-to-conception interval of 59 days in 89.4% of the ewes. When the ewes were bred in the fall (August-November) and again in the spring (January-April) following a winter gestation, the mean conception-to-conception interval was 186.4 days, for 40 ewes, as compared with an interval of 192.5 days, for 35 ewes, for a spring (January-April) conception followed by a fall (August-November) conception; i.e. a summer gestation.

In the Assaf dairy sheep in Israel, Eyal et al. (1973) put them through four lambing periods in 1970/71. Table VIII shows rebreeding intervals after lambing of Assaf sheep during four different lambing periods. It can be seen that lambing was fairly concentrated, with the standard deviations of average lambing dates being small. The fact that the number of days from lambing to conception was greatest in period 2 and smallest in period 4 they reported, was consistent with the seasonal rhythym of the sexual activity of the Assaf sheep (and also the Awassi sheep). The relatively wide range in period 1 was as a result of some of the ewes running into seasonal anestrus and conceiving only during the renewal of sexual activity in the following summer.

Repeatability

Repeatability of number of lambs born in sheep has been estimated

TABLE VIII

REBREEDING INTERVALS OF ASSAF EWES IN ISRAEL IN FOUR LAMBING PERIODS, 1970/71

Period	Average Lambing Date	Number of Ewes Lambing	Days From Previous Lambing	Ewes Kept and Which Reconceived	Days From Lambing to Conception
1	Dec. 1st 1970 ± 13*	102	338 ± 41*	81	94 ± 70*
2	Feb. 4th 1971 ± 21	15	387 ± 35	7	140 ± 59
3	June 11th 1971 ± 16	45	205 ± 55	39	100 ± 36
4	Aug. 29th 1971 ± 18	25	260 ± 23	17	74 ± 30

*Mean ± Standard Deviation.

Source: Eyal et al. (1973). Wld. Rev. Anim. Prod. 9(4) 65-69.

in two ways, either by intra-class correlation or regression of subsequent on early performance. Smirnov (1935) earlier pointed out that there appeared to exist a positive correlation between the prolificacy at the first and the following lambings. He observed in a Stud Flock of Romanov sheep in Russia that ewes which first bore a single lamb subsequently produced on an average 1.89 lambs; those that bore twins, 2.15; and those with triplets, 2.68. He suggested then the possibility of selecting for high prolificacy by the results of the first lambing.

The variance of characters which may be measured more than once on individuals can be considered as the sum of two components: One of these components is caused by permanent differences between measurements on the same individual--temporary effects. Repeatability is the ratio of the variance of permanent differences among individuals to the variance of individuals; each with one record (Morley, 1951). The intra-class correlation or repeatability, r, given by Pirchner (1969) is as follows:

$$r = \frac{V(P)}{V(P) + V(T)},$$

where V(P) is the variance caused by permanent differences among animals and V(T) is the variance caused by differences between the performance of one individual in various periods, that is, temporary differences.

The permanent differences between individuals are caused by differences in genotypes and in permanent environmental factors and influence the performance in all periods. This determines an animal's performance potential during its whole life and is termed "real producing ability" according to Pirchner (1969). Temporary effects are due to the environment and vary from one period to the next. Since the temporary effects are independent from period to period they are as likely to be positive as negative and should tend to average zero over several periods.

Estimates of repeatability obtained by the classic method have been summarized in Table IX. These are all estimates for lambs born per ewe exposed and they range from .05 for Columbia and British breeds (Desai and Winters, 1951b) to .30 for Australian Merinos (Turner et al., 1958). In general, the estimates of repeatability reported for number of lambs born per ewe exposed are very low.

Regression of subsequent on early performance may be estimated by sorting the ewes into categories of 0, 1, 2 etc., lambs born at an early lambing (or lambings), then finding the mean subsequent performance for ewes in each category (Lush, 1956). The difference in subsequent performance associated with changes of 1 lamb in each performance can be pooled to give an overall regression (assuming linearity), or kept separate (Turner, 1969). Early performance can be based on ewes exposed, or ewes lambing in the latter case, the 0 class is omitted for lambs born. The variance caused by temporary environmental influences decreases in averages of n observations to V(T)/n. The regression, b, of the performance potential on averages of n observations becomes:

$$b = \frac{V(P)}{V(P) + \frac{V(T)}{n}} = \frac{nr}{1 + (n-1)r}$$

due Pirchner (1969).

Some reported estimates of repeatability by the regression method are: In Australian Merino ewes between 2-5 years of age, .18 (Kennedy, 1967); in Australian Merino ewes between 2-7 years, .10 ± .02 (Young et

TABLE IX

LITERATURE SOURCES AND ESTIMATES OF INTRA-CLASS CORRELATION REPEATABILITY FOR LAMBS BORN PER EWE EXPOSED

Origin and Breed	Age of Ewes (Years)	Estimate	Reference
Columbia and British breeds in U.S.A.	2-4	.05 ± .03	Desai and Winters (1951b)
New Zealand Romneys	2-7	.12	Rae and Chang (1955)
Australian Merinos	7-10	.30	Turner et al. (1958)
Australian Merinos	2-7	.05 ± .02	Young et al. (1963)
Australian Merinos	2-5	.07 ± .03	Kennedy (1967)
Netherland Texel	---	.09	Sharafeldin (1960)
Scottish Blackface	2-5	.07 ± .01	Purser (1965)
Welsh Mountain	2-5	.10 ± .02	Purser (1965)
Various breed in U.S.A.	2-4	.11	Inskeep et al. (1967)
Clun Forest in Britain	1-4	.09 ± .005	Forrest and Bichard (1974)
Romney Marsh in Poland	1-4	.11	Radomska et al. (1976)
Border Leicester in Australia	1-10	.13	Fogarty et al. (1976)
Galway in Ireland	2-4	.08	Hanrahan (1977)

al., 1963); in Australian Border Leicester ewes, aged between 1-10 years, .12 (Fogarty et al., 1976); and in Clun Forest ewes in Britain, between ages 1-10, .14 ± .02 (Forrest and Bichard, 1974). Again estimates reported here are, generally, very low.

Turner et al. (1958 and 1962) reported on the results of a two way selection for multiple births in Australian Peppin Merino ewes. About 600 ewes were produced in 1947 in Queensland Australia. When the ewes were about five and six years old in 1952 and 1953, an upward (multiple-bearer) and downward (single-bearer) selection lines were established. The ewes used in these selections lines were designated as Base ewes in 1954 and numbered 116. The Base ewes, selected for having multiple or single births at each of two lambings at five and six years of age in 1952 and 1953 have shown a good repeatability. The multiple-bearer group averaged 31 more lambs per 100 ewes mated than the single-bearer group, for six subsequent lambings (1954-1959). Unselected daughters of the base ewes, ranging in age from two to six years, have also shown a difference in lamb drop, those in the multiple-bearer group averaging 21 more lambs per 100 ewes mated. This difference in lamb drop increased with age of the daughter ewes, reaching 31 more lambs per 100 ewes mated, at six years of age.

Young et al. (1963) reported that "the regression of subsequent performance on a difference of 1 lamb at the initial lambing was higher for the difference between 1 and 2 lambs than between 0 and 1 lamb, which indicated that selection for twins is likely to raise fertility in the current flock more rapidly than selection against barrenness". Similar conclusions were drawn by Purser (1965) from the repeatability results derived from an analysis of data from Scottish Blackface and

Welsh Mountain sheep. Whiteman et al. (1963) on which ewes to cull based on their first or second production in the fall reported that ewes that had twins during either or both of their first two years raised 19 and 33 percent larger lamb crops for the next five years than ewes that did not.

Purser (1965) used a rather different method to estimate repeatability of litter size at birth--the regression of performance in any one year on that in the previous years. For this analysis, ewes belonging to any given age-group were grouped afresh each year according to whether they produced either singles or twins (ewes with litter sizes greater than two were ignored). The difference in average litter size produced by these two groups of ewes in subsequent year was then used as the regression coefficient. This method allowed for any possible changes in repeatability with age of ewe or with interval between lambings to be studied especially in the Scottish Blackface ewes.

Purser's (1965) results showed repeatability estimates of .24, .26, .25 and .29 over all ages from 2-5 years and one year intervals between previous and subsequent lambings. These estimates were higher than .07 obtained by the intraclass correlation method. The results showed that the repeatability of litter size from first to second lambing (at 2 and 3 years of age respectively) was significantly lower than for consecutive lambing at older ages. This may be because the ewes could not recover from the strain of twinning at first lambing so easily as at later lambings. Except for the first lambings the repeatability of twinning was essentially the same over all ages between two and six years and all intervals of one to 4 years. In this flock, at least, it was concluded that the repeatability measures some permanent differences between ewes which do not decline with age or time.

Roeper (1960) divided Texel ewes into two groups according to their first lambing at the age of one with either a single or a twin. Van den Bosch (1965) did the same for the same breed in another province in the Netherlands. Their results are presented in Table X. In the Texel breed about 1/3 of the ewes threw twins at first lambing at the age of one year. It seems that a selection difference of one lamb at this age has a marked effect on the number of lambs produced in the following years, with increases ranging from .03 to .17 lambs in the two provinces.

Fogarty et al. (1976) reported on the reproductive performance and mortality of 624 Border Leicester ewes from 1963 to 1974, at Cowra Agricultural Research Station in Australia. They reported that ewes failing to lamb produced .22 fewer lambs at their following lambing than ewes initially producing one lamb. However, there was no additional advantage in subsequent performance for ewes initially producing twin lambs. Extreme culling of dry maiden ewes raised lambs born per ewe joined from 78.8 percent to only 82.7 percent. Ewe mortality was higher among older ewes.

Turner (1969) showed through several analyses that subsequent performance is positively related to early performance, and that this relationship is not linear. She arrived at this conclusion after reviewing about 12 different articles from many parts of the world and some of her own personal analyses. As an example, in one of Turner's flocks (Turner 1966), ewes that bore no lambs at 2 years produced an average of 1.18 lambs per ewe exposed at ages 3-6 years, compared with 1.44 for those which bore 1 initially (a difference of .26) and 1.86

TABLE X

NUMBER OF LAMBS PRODUCED IN LATER YEARS AFTER A SINGLE OR A TWIN AT ONE YEAR OF AGE IN THE NETHERLANDS TEXEL EWES

Age of Ewe (Yrs):		1	2	3	4	5	6
Roeper (1960)							
Single	n	226	226	226	123	61	35
	$\bar{x}$	1	1.78	1.87	1.98	1.85	1.91
Twin	n	158	158	158	105	61	36
	$\bar{x}$	2	1.92	2.01	2.04	1.97	1.94
Difference			+ .14	+ .14	+ .06	+ .12	+ .03
Van den Bosch (1965)							
Single	n	358	358	249	175	92	----
	$\bar{x}$	1	1.66	1.87	1.93	1.99	----
Twin	n	111	111	83	62	35	----
	$\bar{x}$	2	1.83	1.98	2.02	2.14	----
Difference			+ .17	+ .11	+ .09	+ .15	----

Source: Politiek (1965). Wld. Rev. Anim. Prod. 4:59-66.

for those which bore 2 initially (a difference of .42). The two flocks analyzed by Young et al. (1963) and Turner (1966) were initially of the same origin but Flock 1, run in South West Queensland, had had no selection for lambing rate, while Flock 2 run in Southern New South Wales, had been under successful selection for high twinning rate. In both flocks, a change from 0 to 1 in initial classification led to a smaller rise in subsequent performance than a change from 1 to 2.

Turner (1969) went on to say that not all analyses agree in finding the subsequent change greater for an initial difference of 1 or 2 lambs, compared with 0 to 1; in many, the magnitude of the differences is reversed. She pointed out the fact that the regression of subsequent on early performance is not linear. Classic methods of estimating repeatability by intra-class correlation assume linearity, so that the estimates, and the predictions of selection gains based on them, will only be approximate.

CHAPTER III

MATERIALS AND METHODS

Description of Data

The sheep data used in this study were collected at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma, and were part of Oklahoma State University Agricultural Experiment Station Project Number 1519 entitled: The Evaluation of Some Crosses of the Finnish Landrace, Dorset and Rambouillet Breeds as Ewes.

Two hundred and sixty-three crossbred ewes were produced in 1971 and 1972 and were lambed first in 1972 and 1973, respectively. The majority of these ewes were born in March and April of 1971 and 1972. The crossbred ewes represented five combinations of Finnsheep (F), Dorset (D) and Rambouillet (R) breeding. The five breed combinations represented were 1/2D1/2R; 1/4D3/4R; 1/4F1/2D1/4R; 1/4F1/4D1/2R; and 1/4F3/4R. The 1/4F3/4R ewes were produced in 1972 only. The number produced in each of the two years (1971 and 1972) and in each of the breed groups is presented in Table XI.

The crossbred ewe lambs were raised in drylot with their dams and allowed access to a creep which contained a ground ration comprised of 50 percent sorghum grain, 35 percent alfalfa hay, 10 percent soybean mean and 5 percent molasses. Dams were allowed a few hours daily grazing of either small grain or bermuda grass pasture. The ewe lambs

TABLE XI

NUMBER OF EWES PRODUCED IN 1971 AND 1972 IN FIVE BREED COMBINATIONS

Breed of Ewe Combinations[1]	Number and Year Produced		Total
	1971	1972	
1/2D1/2R	26	29	55
1/4D3/4R	28	31	59
1/4F1/2D1/4R	24	30	54
1/4F1/4D1/2R	22	34	56
1/4F3/4R	0	39	39
Total	100	163	263

[1]F = Finnsheep, D = Dorset and R = Rambouillet.

were weaned at approximately 70 days of age and fed a finishing ration similar to the creep ration but with the 10 percent soybean meal replaced by 10 percent alfalfa hay about two weeks to a month after weaning. Upon reaching about 34 kilograms in body weight, the ewe lambs were removed from the drylot and placed on clean pastures to develop and await breeding.

The ewes have been managed under varying conditions to evaluate their suitability as commercial ewes under Oklahoma conditions primarily in regard to their reproductive performance. In the fall breeding seasons of 1971, 1972 and 1973, they were mated to only purebred rams of Suffolk and Hampshire breeding. Starting with the late spring breeding of 1974, they were mated to four purebred and four crossbred rams.

Prior to the ewes going on the accelerated lambing program at four and five years old, they had been lambed in spring 1972, winter 1973 and 1974 and fall 1974 and 1975. A total of 10 and 11 lambing seasons' records were available to evaluate their lifetime performance and repeatabilities. The exact breeding dates and the number of rams used each breeding season are shown in Table XII.

When the crossbred ewes were about four and five years old, they were put on accelerated lambing, that is, lambing every eight months. They went through two cycles of accelerated lambing; three breeding seasons per cycle, starting with the winter of 1976 and extending through the late-spring of 1979. In both cycles under accelerated lambing, breeding seasons were as follows: January-February breeding for summer lambing; May-June breeding for fall lambing and September-October breeding for winter lambing. Each breeding season lasted approximately 45 days.

TABLE XII

BREEDING SEASON DATES AND THE NUMBER OF RAMS USED IN EACH BREED-OF-RAM GROUP (PUREBRED OR CROSSBRED) UNDER PROJECT 1519

		Number of Rams Used for Breeding			
		Purebred[a]		Crossbred[b]	
Breeding Date	Year	HH	SS	HS	SH
Oct. 18 - Dec. 22	1971	2	1	--	--
Sept. 15 - Nov. 6*	1972	5	4	--	--
Aug. 23 - Oct. 19	1973	3	8	--	--
May 15 - July 2	1974	2	2	2	2
May 15 - July 3	1975	2	2	2	2
Jan. 15 - March 5	1976	2	2	2	2
Sept. 15 - Nov. 4	1976	2	2	2	2
May 15 - July 3	1977	2	2	2	2
Jan. 5 - Feb. 24	1978	2	2	2	2
Aug. 25 - Oct. 10	1978	-[c]	2	-[c]	2
May 15 - June 30	1979	1[d]	2	2	1[d]

*Ewes produced in 1972 (Replicate 2) were bred from Oct. 20 - Dec. 20, 1972.

[a]HH = pure bred Hampshire ram and SS = purebred Suffolk ram.

[b]HS = crossbred Hampshire x Suffolk ram and SH = crossbred Suffolk x Hampshire ram.

[c]Two Hampshire and two Hampshire x Suffolk rams' records were deleted because of epididymitis.

[d]One Hampshire and one Suffolk x Hampshire rams' records were deleted because of epididymitis.

Prior to each breeding season, ewes were divided into single sire breeding groups of 28-36. Breeding groups were equalized as closely as possible for number of ewes of each crossbred group and for number of ewes rearing zero, one or multiple lambs the previous lambing. In each breeding pasture each breeding season four to five ewes of other breeding whose results were not pertinent to this study were run with these crossbred ewes. A Hampshire, Suffolk, Hampshire x Suffolk or Suffolk x Hampshire sire was placed with each breeding group. A total of eight rams (four purebreds and four crossbreds) were therefore used each breeding season.

Prior to the start of each breeding season, all rams were electro-ejaculated and only those rams with normal appearing semen, as evaluated by microscopic examination, were used in the breeding pastures. Rams which appeared to be slow breeders in the mating pastures were replaced with reserve rams. There was an indication from the mating and lambing records, that at least one of the season's reproduction records in cycle 2 was affected by epididymitis to a variable extent. For winter 1979 records on ewes mated to two Hampshire and two Hampshire x Suffolk rams were deleted and the fall of 1979 the records on ewes mated to one Hampshire ram and one Suffolk x Hampshire ram were deleted because of epididymitis (see Table XII).

Ewes nursed their lambs for approximately 70 days after each lambing, except that ewes that lambed late sometimes had their lambs weaned at younger ages because of the next breeding season. Following the breeding season, ewes grazed bermuda or native pastures and were supplied alfalfa hay when grass became scarce or covered with snow. From four weeks prior to lambing until lambing, the ewes were fed approximately .2-.4 kilograms of sorghum grain per head per day.

Each lambing season, ewes lambed under close supervision in a barn or adjacent pasture depending on the weather. Shortly after parturition, the lambs were identified and weighed, and the ewe and her lamb(s) were placed in an individual lambing pen where they remained for approximately three days during which time the lambs were docked. After lambs were about a week old in the summer lambings, both ewes and lambs had access to sweet sudan, pearl millet or alfalfa pasture. Dry weather usually forced the feeding of supplemental alfalfa and grain towards the end of the lactation periods. For winter and fall seasons, ewes and lambs grazed small grain pastures after lambs were about a week old.

Over the various seasons, routine sheep management chores such as foot trimming and drenching were carried out on the ewe flock. Health problems were taken care of as they came; either consulting a veterinarian or the shepherd with his assistants took care of them.

There were 70.9; 86.4; 57.4; 73.2 and 71.8 percent of the ewes left in 1/2D1/2R; 1/4D3/4R; 1/4F1/2D1/4R; 1/4F1/4D1/2R and 1/4F3/4R groups, respectively, when project 1519 was terminated in December 1979. Longevity of the five breed groups have been shown in Figure 4, in the Appendix. Numbers of ewes alive and present at each lambing season in each breed group have also been shown in Table XXXIII in the Appendix.

Statistical Methods

Traits that were studied under accelerated lambing were: Fertility or the number of ewes lambing per total number of ewes exposed; prolificacy or the number of lambs born per ewe lambing and number of lambs born per number of ewes exposed, an overall measure of reproductive efficiency. Under accelerated lambing, a section was also devoted to studying the intervals between lambings and conceptions.

Repeatability of number of lambs born were estimated using two methods: Intra-class correlation and regression of subsequent on earlier lambings, as an aid to predicting the lifetime performance of the ewes. The repeatability studies used the lifetime records of the ewes.

The objective under accelerated lambing was to be able to compare the five breed groups for their performance in the two cycles and between the three breeding seasons--winter, fall and late-spring as depicted in Figure 1. The performance of pure- and crossbred rams of Hampshire and Suffolk breeding when mated to these same ewes in January-February, May-June and September-October was also evaluated.

Cycle	Breeding Season		
1	Winter 1976	Fall 1976	Late-Spring 1977
2	Winter 1978	Fall 1978	Late-Spring 1979

Figure 1. Organization of Accelerated Lambing Data

<u>Fertility, Prolificacy and Number of Lambs Born Per Ewe Exposed</u>

Fertility as used here was defined as:

$$\frac{\text{Number of Ewes Lambing}}{\text{Total Number of Ewes Exposed}} \times 100,$$

for each breed group, each season. The total number of ewes exposed each season varied from breed to breed and from season to season. All the percentages were therefore not based on the same total count (i.e. the same denominator) and analysis of variance technique for percentages based on unequal numbers (Cochran, 1943) were employed. Prior to actual analyses of fertility data, preliminary analyses were performed to determine which type of weighting would be appropriate in these data. The amount of binomial variation in the data was within the range of 17-20 percent, and extraneous variation was within 80-83 percent. The data were, therefore, analyzed by the method of unweighted means using the proportion of ewes lambing within a breed group as the means under analysis. The raw percentages were analyzed and no angular transformation was used.

Statistical analyses of the fertility data were accomplished by using the computer program package entitled Statistical Analysis System (SAS) developed by Barr and Goodnight (1979) at North Carolina State University. The GLM procedure was used. Analyses were performed first within cycle-season and secondly within seasons. An overall analysis was also performed. The same models were used for prolificacy, which was defined as:

$$\frac{\text{Number of Lambs Born}}{\text{Number of Ewes Lambing}},$$

and the number of lambs born per total number of ewes exposed.

In the models used for fertility, rams within breed of ram term was included in the within cycle-season model. The reason for doing this was to see if differences existed in the performance of individual rams within a particular breed of ram. From the within cycle-season analysis, no significant differences between rams within a breed were found (F values for the six seasons under accelerated lambing ranged from F = .13 to F = .71). Therefore in the within season model, ram within breed of ram term was not included. The breed of ram term was however given a different meaning in the within season analysis, in that the values obtained for purebred and crossbred rams were respectively averaged to obtain class of ram (either purebred or crossbred) effects.

The class of ram effects were of particular interest in the within season analysis so that the performance of purebred and crossbred rams could be assessed. All interaction terms involving breed of ram with other effects, in this model, however, had purebred Suffolk, purebred Hampshire and their reciprocal crosses involved and not the averages for purebred and crossbred rams.

The purpose of the within cycle-season model was to see if differences existed between the five breeds of ewes used and also to see if differences existed between individual rams within a breed of ram. The model used was:

$$Y_{ijkl} = \mu + w_i + r_j + (wr)_{ij} + Z_{k(j)} + e_{l(ijk)}$$

where Y_{ijkl} is the observed value of the lth ewe in the ith breed of ewe mated to the kth ram within the jth breed of ram.

μ is the mean for a particular season within a cycle.

w_i is the ith breed of ewe effect.

r_j is the jth breed of ram effect.

$(wr)_{ij}$ is the interaction of the ith breed of ewe and the jth breed of ram.

$Z_{k(j)}$ is the kth ram within the jth breed of ram.

$e_{l(ijk)}$ is the random errors, such that e ~ NID (O, σ^2).

Residual mean squares in each season within a cycle were tested by Bartlett's homogeneity test for variances as described by Steel and Torrie (1960). A pooled analysis was then performed by pooling seasons that were the same in the two cycles.

The model used by season was:

$$Y_{ijpl} = \mu + w_i + r_j + (wr)_{ij} + C_p + (wc)_{ip} + (rc)_{jp} + (wrc)_{ijp} + e_{l(ijp)}$$

where,

Y_{ijpl} is the observed value of the lth individual in the ith breed of ewe mated to the jth breed of ram in the pth cycle.

μ is the mean for season.

w_i is the ith breed of ewe effect.

r_j is the jth class of ram effect (only in fertility data), otherwise it is the jth breed of ram effect.

$(wr)_{ij}$ is the interaction of the ith breed of ewe and jth breed of ram.

C_p is the pth cycle effects.

$(wc)_{ip}$ is the interaction of the ith breed of ewe and pth cycle.

$(rc)_{jp}$ is the interaction of the jth breed of ram and pth cycle.

$(wrc)_{ijp}$ is the interaction of the ith breed of ewe and the jth breed of ram and the pth cycle.

$e_{l(ijp)}$ is the random errors; such that e ~ NID(O, σ^2).

An overall analysis was also performed for fertility, prolificacy and number of lambs born per ewe exposed. This was done by including season in the model and the interaction of season with terms that were significant or approaching significance when the analysis was performed within seasons. The reason for doing an overall analysis was to identify the significant sources of variation.

The overall model for fertility, prolificacy and number of lambs born per ewe exposed was:

$$Y_{ijpql} = \mu + w_i + r_j + c_p + s_q + (sc)_{qp} + (sr)_{qj} + (sw)_{qi} + a + e_{l(ijpq)}$$

where,

Y_{ijpql} is the observed value on the lth individual in the ith breed of ewe mated to the jth breed of ram in the qth season in the pth cycle.

μ is the overall mean.

w_i, r_j and c_p are the same as defined in the within season model.

s_q is the qth season effects.

$(sc)_{qp}$ is the interaction of the qth season by pth cycle.

$(sr)_{qj}$ is the interaction of the qth season by jth breed of ram.

$(sw)_{qi}$ is the interaction of the qth season by ith breed of ewe.

a represents the three factor interactions of breed of ewe, breed of ram and cycle, pooled from the within season analysis.

$e_{l(ijpq)}$ is the random errors; such that e ~ NID (O, σ^2).

Interval From Lambing to Conception

On all ewes that had consecutive lambings the lambing date in one season was subtracted from the conception date following the lambing date in order to get the interval from lambing to conception. The analysis was performed on the interval and the actual date of lambing of an ewe was used as a covariable. Lambing to conception interval was analyzed first, within cycle-season, secondly, within seasons by pooling seasons that were the same in the two cycles. Finally, an overall analysis was performed.

Except for the covariable terms, the models used in the within cycle-season and the within season analyses for lambing to conception interval are similar to those used in the fertility, prolificacy and number of lambs born per ewe lambing analyses. Therefore only the final model will be presented for lambing to conception interval. The purpose of the overall model was to identify the significant sources of variation and also to obtain average intervals from fall lambing to winter conception, from summer lambing to fall conception and from winter lambing to late spring conception.

The overall model for lambing to conception intervals was:

$$Y_{ijpql} = \mu + w_i + r_j + c_p + s_q + b(D_{ijpql}) + (sc)_{qp} + (sr)_{qj} + (sw)_{qi} + a + e_{l(ijpq)}$$

where,

Y_{ijpql} is the observed interval of the lth individual of the ith breed of ewe mated to the jth breed of ram in the qth season in the pth cycle.

μ is an overall constant.

w_i is the ith breed of ewe effect.

r_j is the jth breed of ram effect.

c_p is the pth cycle effects.

s_q is the qth season effects.

b is the regression coefficient of the interval on the lambing date.

D_{ijpql} is the lambing date of the lth ewe in the ith breed of ewe mated to the jth breed of ram in the qth season in the pth cycle.

$(sc)_{qp}$ is the interaction of the qth season and the pth cycle.

$(sr)_{qj}$ is the interaction of the qth season and the jth breed of ram.

$(sw)_{qi}$ is the interaction of the qth season and the ith breed of ewe.

a represents three factor interactions of the ith breed of ewe, jth breed of ram and pth cycle, pooled from the within season analyses.

$e_{l(ijpq)}$ is the random errors, such that e ~ NID (O, σ^2).

In the analyses within cycle-season and within seasons, tests of significance were performed and where a term was not or did not approach significance it was deleted from the model before the final analysis.

Repeatability

All lambing records available on all ewes since their production in 1971 and 1972 (that includes all lambing opportunities) were used in the repeatability studies. The ewes were first lambed at yearly intervals in winter 1972, 1973 and 1974. They were bred in May-June

1974 for the first fall lambing in the fall of 1974, that was about nine months lambing interval from the previous lambing. In May-June, 1975, they were bred to lamb in fall, 1975, but with a one year interval from the previous lambing. They were bred in January-February, 1976, to lamb for the first time in Summer 1976, and thereafter followed a program of lambing every eight months in the winter and fall in that order, with their respective breeding dates in September-October and May-June.

In 1971, 1972 and 1973 fall breeding, only purebred Suffolk and Hampshire rams were used. Starting from the late spring of 1974 breeding and continuing on to the late spring of 1979 breeding, four purebred rams and four crossbred rams were used each season. They were of Suffolk and Hampshire breeding and their reciprocal crosses, and were a minimum of 15 months old at breeding time. Number of rams used in 1971, 1972 and 1973 fall breeding were variable, see Table XII. The conditions under which these ewes were managed were, therefore, variable from year to year. Lambings occurred at yearly intervals and then at eight-monthly intervals; seasons in which the lambings occurred were also variable-spring, late winter, winter, summer and fall (Table XIII).

There were also two replicates of ewes produced. One replicate was produced in 1971 and the other replicate in 1972. After the fall of 1979 lambing, at which time the project was terminated, some of the ewes had 10 lambing opportunities while some had 11 opportunities, these are shown in Table XIII. These lambing opportunities were defined as the lambing events for the purposes of the analyses.

There were 263 ewes at the start of the project and some of these ewes remained through 10 lambing events. In order to reduce the size of the X'X matrix, a computational technique called the Absorb State-

TABLE XIII

NUMBER YEARS AND SEASONS IN WHICH LAMBING OCCURRED FOR EWES IN REPLICATES ONE AND TWO UNDER PROJECT 1519

Number of Lambings	Year of Lambing		Season of Lambing
	Rep. 1	Rep. 2	
1	1972[a]	----	Spring
2	1973	1973[b]	Late Winter
3	1974	1974	Winter
4	1974	1974	Fall
5	1975	1975	Fall
6	1976[c]	1976[c]	Summer
7	1977	1977	Winter
8	1977	1977	Fall
9	1978	1978	Summer
10	1979	1979	Winter
11	1979	1979	Fall

[a]Replicate 1 ewes were produced in 1971 and lambed for the first time at one year of age in 1972.

[b]Replicate 2 ewes were produced in 1972 and lambed for the first time at one of age in 1973.

[c]Accelerated lambing was started with the Summer 1976 lambing.

ment in the SAS package developed by Barr and Goodnight (1979) was employed. This computational technique combined the effects of each class of ram, each season of lambing and the year in which an ewe was produced so that these effects would not contribute to the size of the X'X matrix.

Essentially the lambing records used in the repeatability study were adjusted for class of ram, season of lambing and the year in which an ewe was produced.

Intra-class correlation method of estimating repeatability. This was carried out in SAS using the Varcomp procedure developed by Barr and Goodnight (1979) at North Carolina State University. The model used was:

$$Y_{klm} = \mu + a + c_k + d_{l(k)} + e_{m(kl)}$$

where,

Y_{klm} is the mth observation on the lth individual within the kth breed of ewe.

a is the effect of each combination of class of ram, lambing event and the year in which an ewe was produced.

c_k is the kth breed of ewe.

$d_{l(k)}$ is the lth ewe within the kth breed of ewe.

$e_{m(kl)}$ is the random error, such that $e \sim NID\ (O, \sigma^2)$.

Analysis was performed first within breed of ewe groups. That means in the above model c_k was deleted and d_l represented the lth individual ewe effect within that particular breed. Analyses were then pooled over breed of ewe to get one estimate of repeatability.

Fisher's (1946, Section 39) formula was used to calculate the approximate standard error on the pooled intra-class correlation.

"Regression Method" of estimating repeatability. The "regression method" of estimating repeatability as used here was suggested by Lush (1956) and later used by Young et al. (1963). In this method the regression of the adjusted average number of lambs at later lambings on the number of lambs at the initial lambing was used. For example, in the calculation of the repeatability of the records at their first lambing at one year old, all the ewes were sorted into those which gave birth to no lambs, to one lamb, and to two lambs. The mean number of lambs born by the same ewes in the second and successive years, in each of the three groups was calculated. Similarly in their second lambing, the ewes were sorted according to the number of lambs born and here four groups (group 0, group 1, group 2, and group 3) were available.

$$Y_{klmn} = \mu + a + c_k + d_l + dd_l + (c \times dd)_{kl} + f_{m(kl)} + e_{n(klm)}$$

where,

Y_{klmn} is the nth observation on the mth ewe within the kth breed of ewe and the lth lambing class.

a is the effect of each combination of class of ram, lambing event and year of production of the ewe.

c_k is the kth breed of ewe effect.

d_l is the linear effects of the lth lambing class.

dd_l is the quadratic effects of the lth lambing class.

$(cxdd)_{kl}$ is the interaction of the kth breed of ewe and the quadratic effects of the lth lambing class.

$f_{m(kl)}$ is the mth ewe within the kth breed of ewe and the lth lambing class.

$e_{n(klm)}$ is the random errors, such that $e \sim NID\ (0, \sigma^2)$.

A separate model with dd_l, $(cxdd)_{kl}$ and $f_{m(kl)}$ deleted from model given above was run in order to get estimates of the regression coefficients of lambs born at later lambings on initial or second lambing classes. The analysis was done first, within breed of ewe, in which case c_k and $(cxdd)_{kl}$ were deleted from the model given above. The term f_m, therefore, represented individual ewes within a breed group. The differences between groups 0 and 1 and between 1 and 2 and 2 and 3 in adjusted mean number of lambs subsequently born were pooled to obtain a single estimate of repeatability.

The following model was used to facilitate pooling.

$$Y_{kl} = \mu + a + c_k + d_l + f_{m(kl)} + e_{m(kl)}$$

Definition of terms are the same as given above. Ewe within breed of ewe and lamb class term $[f_{m(kl)}]$ was included in this model so that it could be pooled.

CHAPTER IV

RESULTS AND DISCUSSION

The results and discussion will be presented in three main sections: 1) Reproductive performance under accelerated lambing which will include fertility, prolificacy and number of lambs born per ewe exposed. 2) Lambing to conception intervals under accelerated lambing and 3) Repeatability estimates.

The objectives concerning reproductive performance under accelerated lambing were twofold: First, to compare the reproductive performance of the five crossbred ewe groups when mated in winter, fall and late spring. Secondly, to compare two classes of rams, purebred and crossbred rams of Hampshire and Suffolk breeding when they are mated to these same ewes in January-February, September-October, and May-June.

For fertility, prolificacy and number of lambs born per ewe exposed, analyses were performed first, within cycle-season to determine if differences existed between the five breeds of ewes used in the study and evaluate differences between individual rams within breeds of ram. Where there were no differences between rams of the same breeding, averages were found so as to get the class of ram (either purebred or crossbred) effect. Secondly, analyses were performed within seasons to evaluate season to season variations between the five breed of ewe groups and between breed of rams and where necessary between classes (purebred or crossbred) of rams. Seasons that were the same in the two cycles were pooled for the within season analyses.

Overall analyses were also performed for the three traits in order to identify the significant sources of variations. These important or significant sources of variations will later be discussed separately for all the three traits. Analyses of Variance for fertility and prolificacy is shown in the Appendix, in Table XXXIV.

In the estimation of values for fertility and number of lambs born per ewes exposed, the same number of ewes were involved. In the prolificacy study, the numbers were different since records on those ewes that produced no lamb(s) at each lambing were deleted before the analyses, according to the definition of prolificacy. The various numbers involved in each estimation have been shown, where necessary, in the tables, in the body of the thesis either in parenthesis or under 'n'. In the Appendix, they have been shown under the letter 'n'.

Significant sources of variation present, from the overall analysis for fertility were: Season of breeding by cycle interactions ($P<.01$); class of ram (purebred and crossbred) by season of breeding interactions ($P<.05$); and breed of ewe effects ($P<.05$). Shown in the Appendix in Tables XXXV to XXXVII are some tables which were not used in the discussion *per se* but which lend understanding to what occurred in the analyses for fertility.

Breed of ram least squares means for fertility in the three breeding seasons, averaged over the two cycles of accelerated lambing are presented in Table XXXV. Values for fertility in the winter and fall breeding seasons were not significantly different from each other. Values obtained for late-spring breeding season were significantly different ($P<.05$) for purebred and crossbred rams.

Least squares means for fertility obtained for each breed of ewe combination in each of the three breeding seasons under accelerated lambing program are shown in Table XXXVI. Again values of ewe fertility obtained were high and not significantly different from each other in the winter and fall breeding seasons. Values of ewe fertility obtained for 1/2D1/2R, 1/4D3/4R and 1/4Finn ewe groups, however, were significantly different from each other ($P<.05$) during the late-spring breeding season.

Breed of ewe by breed of ram least squares means for fertility in winter, fall and late-spring under accelerated lambing are presented in Table XXXVII. Late-spring breeding results indicated the fertility in May-June to be very low.

From the overall analysis for prolificacy, significant sources of variation were: Breed of ewe combination effects ($P<.01$). Based on the data available, breed of ewe combination effects did not show any significant interactions with seasons ($F = 1.52$), so breed of ewe combination effects were averaged over all three breeding seasons. There were also significant season of breeding by cycle interactions ($P<.01$).

Breed of ewe combination least squares means for prolificacy when they are bred in winter, fall and late-spring under accelerated lambing program is presented in the Appendix, Table XXXVIII. Prolificacy, averaged over all breed of ewe groups is shown in the same table. Prolificacy was low in the late-spring breeding, 1.35. It was intermediate in the winter breeding season 1.67 and was high for fall breeding season, 1.80.

Number of lambs born per ewe exposed was presented as an index of flock productivity. A table showing breed of ewe combination least squares means for this trait in the three breeding seasons is presented in the Appendix, Table XXXIX.

Overall measure of reproductive performance or number of lambs born per ewe exposed, generally followed the pattern for fertility. Values were high when ewes were bred in winter and fall (1.53 and 1.62). A low value of .69 was obtained when ewes were bred in the late-spring. These figures are shown in Table XXXIX.

Reproductive Performance Under Accelerated Lambing

The five breed groups will be discussed individually for fertility. For prolificacy, the ewes will be sorted into three main groups - 1/2D1/2R; 1/4D3/4R and 1/4Finns. This is because the 1/4Finn ewes produce similarly for prolificacy.

Fertility

In cycle one, under accelerated lambing, the breeding dates followed rigidly at eight monthly intervals. In cycle two, the breeding dates were modified. The winter breeding season was advanced by 10 days and the fall breeding season by 20 days. Thus, the interval from winter lambing to late-spring rebreeding was lengthened by 20 days. This is illustrated in Figure 2 which shows the schedule followed under accelerated lambing. Average conception dates ($\bar{M}$), average lambing dates ($\bar{L}$), the lengths of the breeding seasons (represented by thick horizontal bars), and the breeding seasons indicated at the bottom of the figure (i.e. winter, fall and late-spring) are all shown in Figure 2.

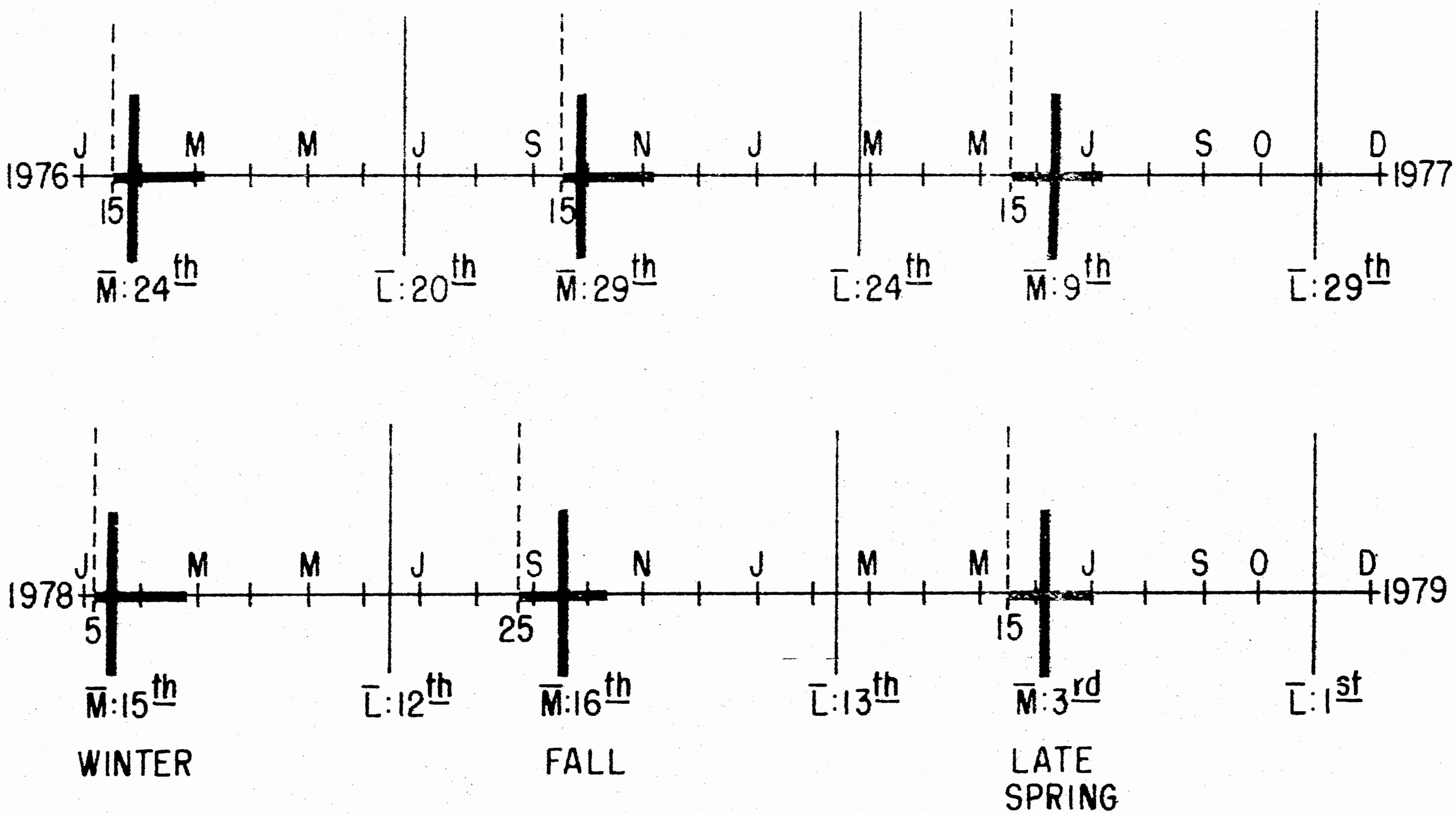

Figure 2. Accelerated Lambing and Breeding Schedule Showing the Lengths (Thick Horizontal Bars) and Seasons of Breeding (Winter, Fall and Late-Spring); Average Conception Dates ($\bar{M}$) and Average Lambing Dates ($\bar{L}$)

The alterations in the breeding seasons were made because of a poor May-June breeding which resulted in a very low fall, 1977, fertility. The changes in the breeding dates probably caused the season of breeding by cycle interactions for fertility ($P<.01$); which is shown in Table XIV.

In the first cycle following exactly eight-month lambing intervals, fertility in the late-spring was very low, 38.5 percent. Fertility in the winter and fertility in the fall were about the same. As a result of advancing the winter and fall breeding seasons by 10 and 20 days, respectively (see Figure 2), a price was paid for by a decreased fertility in winter and fall breeding seasons (92.8 and 94.7 percent compared to 85.7 and 88.7 percent in cycle one). Fertility in the late-spring of cycle two, however, was greatly improved to 61.8 percent.

Land and McClelland (1971) lambing Finn-Dorset ewes twice in a year reported that the proportion of ewes lambing was reduced from 93 percent to 32 percent by the occurrence of lambing six months previously. Under this schedule of lambing every eight months fertility for lambing in the fall was generally low (38.5 and 61.8 percent in cycles one and two).

Whiteman et al. (1972) in Dorset, Rambouillet and Dorset x Rambouillet ewes in twice-yearly lambings over four fall and four spring seasons reported 35 percent ewes lambing in the fall and 84 percent ewes lambing in the spring. Walton and Robertson (1974) also reported similarly lower fertility for fall lambing than for spring lambing and they agreed with Whiteman et al.'s (1972) suggestion that by the middle of March some of these ewes were in the anestrus state.

Thomas and Whiteman (1979) on the productivity of spring and fall

TABLE XIV

BREEDING SEASON BY CYCLE LEAST SQUARES MEANS FOR FERTILITY UNDER TWO CYCLES OF ACCELERATED LAMBING

Cycle	Breeding Season Winter	Fall	Late Spring
1	94.7 ± 1.5	92.8 ± 1.7	38.5 ± 3.1
	(226)[a]	(222)	(218)
2	88.7 ± 2.3	85.7 ± 3.3	61.8 ± 4.0
	(203)	(98)	(144)

[a]Number of ewes involved in the estimation are given in parentheses.

lambing ewes suggested that the Finnsheep breed is less able to conceive to May-June mating to lamb in the fall than is the Rambouillet breed; and that an increase of Finnsheep genes at the expense of Rambouillet genes resulted in decreased percentage of ewes lambing in the fall.

Carter and Copenhaver (1974) in 1/2Finn x 1/2Rambouillet ewes and 1/4Finn x 3/4Rambouillet ewes when bred in March-April, 1973, to lamb in the fall of 1973, reported 83 and 71.4 percent fertility for these two groups, respectively. When the ewes were bred in September to lamb in winter, 1974, they reported 60 and 58.3 percent fertility, respectively, for the same two groups. The number of ewes exposed, however, were very few in the two groups: There were five ewes exposed for the 1/2F1/2R and 12 ewes exposed for 1/4F3/4R. Those ewes that lambed in September had their lambs weaned at about five weeks of age and were rebred in November to lamb in April-May, 1974. They reported 81 and 70.3 percent fertility in the two groups, respectively.

Under the system of lambing three times in two years, lambing percentages were high and about the same when breeding occurred in the winter and fall (averages over the two cycles were 91.7 and 89.3 percent, respectively). Fall lambing, however, indicated the fertility in May-June breeding, averaged over the two cycles, to be low 50.2 percent.

Purebred Vs. Crossbred Ram Performance

Individual purebred rams and individual crossbred rams' fertility values in the analyses within seasons, were averaged to obtain the class of ram (purebred and crossbred) by season of breeding interactions for fertility. These interactions are presented in Table XV.

TABLE XV

CLASS OF RAM (PUREBRED OR CROSSBRED) BY SEASON OF BREEDING LEAST SQUARES MEANS FOR FERTILITY UNDER ACCELERATED LAMBING

Class of Ram	Season of Breeding[1]		
	Fall	Winter	Late-Spring
Purebred	88.7 ± 2.7	92.9 ± 1.9	41.0 ± 3.5
	(112)[2]	(216)	(180)
Crossbred	93.1 ± 2.0	91.3 ± 1.9	62.4 ± 3.5
	(208)	(213)	(182)

[1]Fall breeding occurred in September-October, Winter breeding in January-February and Late Spring breeding in May-June.

[2]Number of ewes settled by rams are in parentheses.

Crossbred rams settled 4.4 percent more ewes than purebred rams in the fall breeding season (P>.05). In the winter breeding season purebred and crossbred rams settled virtually the same percent of ewes (92.9 vs. 91.3). In the late-spring breeding, crossbred rams settled 21.4 percent more ewes than purebred rams and this difference was significantly different from zero, P<.05.

The high fertility rates of all ewes when mated in September-October (to lamb in winter) and in January-February (to lamb in summer) suggests that a high proportion of the ewes were sexually active during these periods. These high levels of sexual activity in the ewes would not allow the increased aggressiveness of crossbred rams to show itself in the form of greater conception rates, if crossbred rams are indeed more aggressive.

Season of mating may have been a major factor in the low fertility in the late-spring. May and June is a season of low sexual activity in the ewe, and conception rates are generally lower to matings during this period than to matings at other times during the year. If crossbred rams are more aggressive in the breeding pastures than purebred rams, crossbred rams may stimulate some ewes to a higher level of sexual activity which will allow them to conceive. In fact the mating records would indicate this fact.

A summary of the May-June matings is presented in Table XVI. In the first 17 days, more ewes were mated by crossbred rams than by purebred rams in both May-June, 1977 (57 vs. 46), and 1979 (40 vs. 23) breeding. Also fewer ewes were not mated at all by crossbred rams than by purebred rams in both years (25 vs. 45).

Mauléon and Dauzier (1965) concluded, in Ille-de-France ewes, that

TABLE XVI

DISTRIBUTION OF THE MATING ACTIVITY OF THE EWES IN MATING TO EITHER PUREBRED OR CROSSBRED RAMS IN MAY-JUNE 1977 AND 1979 BREEDING; IN THE FIRST 17 DAYS AND TWO OR MORE 17-DAY CYCLES

	1977	1979
Number of Ewes Exposed	221	168[a]
First 17 Days Matings		
Number of ewes that mated	103	81
Number that mated to purebreds	46	23
Number that mated to crossbreds	57	40
2 or More 17-Day Cycle Matings		
Number of ewes that mated	138	83
Number that mated to purebreds	69	40
Number that mated to crossbreds	69	43
Number of Ewes Not Mated		
Number of ewes that did not mate to purebreds	25	20
Number of ewes that did not mate to crossbreds	19	6

[a]Fewer ewe records used in Fall 1979 because of ram epididymitis.

seasonal anestrus markedly prolonged the post-partum interval in ewes that lambed early in the year. Whiteman et al. (1972) and Walton and Robertson (1974) also arrived at the same conclusion. In May-June breeding following February lambing, it is therefore likely that a large number of ewes would still be in the anestrus state and they would gradually get out of this state with the continuous presence of the rams "ram effect" amongst them as the breeding season progresses (Schinckel, 1954a,b; Lishman, 1969; Ngere and Dzakuma, 1975).

The purebred rams, during the May-June breeding-season, were apparently not as sexually aggressive and crossbred rams were able to effect more matings than the purebred rams. Probably a few of the ewes remained in the anestrus state all the while during the 45-day breeding period allowed, hence their unwillingness to mate. In this group of non-maters, from the mating records, a majority of them belonged to ewes that were allotted to purebred rams at the time of breeding.

Hulet et al. (1980) pointed out the fact that a key to accelerated lambing without hormone therapy would be to breed the ewes sufficiently early in the season so that they will lamb and get back into breeding condition again before the end of the breeding season. One technique which they suggested might be used to induce early breeding during the breeding season was the "ram effect"; so that the opportunity of breeding a second time might be enhanced.

The data suggested that in the fall breeding (September-October) and winter breeding (January-February) it probably does not make much difference as to which class of ram (either purebred or crossbred) is used; but in the late-spring breeding (May-June), crossbred rams were superior in breeding to purebred rams in the breeding pastures.

Ewe Performance

The reproductive performance of 1/2D1/2R ewe group under Oklahoma conditions has been amply documented by Thrift and Whiteman (1969a,b,c). Also the performance of 1/2D1/2R ewes in a twice-yearly lambing program has been shown by Whiteman et al. (1972). All other breed groups in this study, therefore, were compared to 1/2D1/2R ewes.

The three main comparisons of interest, concerning the breed of ewe combination groups, in the three breeding seasons are shown in Table XVII. They were: The mean performance of all other breed groups subtracted from the performance of 1/2D1/2R ewes; the average performance of the three Finnsheep groups were deducted from that of 1/2D1/2R group; and lastly the performance of 1/4D3/4R group was subtracted from that of 1/2D1/2R group.

In winter, differences obtained in percent ewes conceiving were all in favour of the other groups; but the differences were not significantly different from zero. All other breed groups were higher in fertility, ranging from 1.6 to 5.3 percent more lambs, than 1/2D1/2R group.

The differences in percent ewes conceiving in the fall were not significantly different from zero, however, 1/2D1/2R ewes produced 3.1 percent more lambs than all other breed groups combined. The 1/2D1/2R group also produced 4.4 percent more lambs than the 1/4Finns. The 1/4D3/4R group, however, were slightly better than 1/2D1/2R group by .8 percent lambs.

Differences in percent ewes conceiving during the late-spring breeding would indicate the higher fertility for 1/2D1/2R ewes over the two other groups when the ewes were bred in May-June. The differences,

TABLE XVII

COMPARISONS AMONG THE THREE PRIMARY EWE BREED COMBINATION GROUPS FOR FERTILITY IN WINTER, FALL AND LATE-SPRING BREEDING SEASONS UNDER ACCELERATED LAMBING

Season of Breeding	Comparison Between Groups[1]	Differences in Percent Ewes Lambing
Winter	1/2D1/2R vs. Others[2]	-4.4 ± 3.2
	1/2D1/2R vs. 1/4Finns	-5.3 ± 3.2
	1/2D1/2R vs. 1/4D3/4R	-1.6 ± 3.9
Fall	1/2D1/2R vs. Others	3.1 ± 2.9
	1/2D1/2R vs. 1/4Finns	4.4 ± 3.0
	1/2D1/2R vs. 1/4D3/4R	-0.8 ± 3.2
Late Spring	1/2D1/2R vs. Others	19.2 ± 6.4*
	1/2D1/2R vs. 1/4Finns	18.5 ± 6.7*
	1/2D1/2R vs. 1/4D3/4R	21.0 ± 7.6*

[1]Comparisons were made by deducting the ewe fertility value for the second group from that of the first.

[2]F = Finnsheep, D = Dorset and R = Rambouillet.

*Significant at $P < .05$.

ranging from 18.5 to 21 percent, in the fall, were significantly different from zero at $P < .05$.

With respect to the breed of ewe combination groups, late-spring breeding favoured the use of 1/2D1/2R ewes. Under the conditions existing in Oklahoma, in winter and fall breeding seasons, any of the ewe breed combinations could be used with the expectation of getting about 90 percent of them to conceive.

Prolificacy

From the data available, breed of ewe combination did not appear to interact with lambing seasons ($F = 1.52$); so the breed of ewe combination least squares means for prolificacy were averaged over the two cycles and over the three breeding seasons. The breed of ewe combination involved, the number of ewes present in each breed combination for the estimation and the least squares means are presented in Table XVIII.

The 1/4Finn ewes demonstrated the highest prolificacy of 1.66 which was significantly different ($P < .05$) from the prolificacy obtained for 1/2D1/2R (1.56) and 1/4D3/4R (1.50). The 1/4Finns produced .10 and .16 more lambs than 1/2D1/2R and 1/4D3/4R groups, respectively.

An overall mean prolificacy of 1.61 was obtained. This overall mean was lower than the value of 2.1 reported by Robinson and Ørskov (1975) for Finn x Dorset ewes, but they used hormone therapy and artificial light treatment in their study. The estimate (1.61) was also lower than 2.3 reported for 1/4F3/4R (Carter and Copenhaver, 1974) in one cycle of lambing three times in two years. Their breeding period in Virginia, U.S.A., was in March-April to lamb in September. Those

TABLE XVIII

BREED OF EWE COMBINATION LEAST SQUARES MEANS FOR PROLIFICACY AVERAGED OVER TWO CYCLES AND THREE SEASONS OF ACCELERATED LAMBING

Breed of Ewe Combinations[1]	n	Least Squares Means
1/2D1/2R	197	1.56 ± .04
1/4D3/4R	208	1.50 ± .04
1/4F1/2D1/4R	147	1.62 ± .05
1/4F1/4D1/2R	176	1.69 ± .05
1/4F3/4R	129	1.67 ± .05
1/4F[2]	452	1.66 ± .03
Overall	857	1.61 ± .02

[1]F = Finnsheep, D = Dorset and R = Rambouillet.

[2]Average over the three 1/4F groups.

that failed to lamb were then bred in September. Those that lambed in September were rebred in November.

In this study in Oklahoma, the breeding seasons were: September-October to lamb in winter, January-February to lamb in summer, and May-June to lamb in the fall. Also in this study the 1/4F3/4R group produced 1.67 lambs under two cycles of lambing three times in two years. This was again lower than the 2.3 reported in Virginia by Carter and Copenhaver (1974) for 1/4F3/4R ewes.

Significant season of breeding by cycle interactions were also obtained for prolificacy ($P<.01$). These are shown in Table XIX. Despite the change in advancing the breeding dates in January-February by 10 days in cycle two, the winter prolificacy was increased by .23 more lambs. The 20 days advance in September-October breeding, also in cycle two, however, decreased the fall prolificacy by .10 lambs. There was virtually no change in prolificacy when breeding in the late-spring.

After lambing in the fall of 1974, these same ewes were lambed again in the fall of 1975, at an interval of a year (see Table XIII). About 71.5 percent of the ewes had lambed in the fall of 1975 before they were rebred in January-February, 1976, for the first summer lamb-under accelerated program. Starting with the fall of 1975 lambing, prolificacy of those ewes that lambed in two successive seasons were compared to the prolificacy of their contemporaries that failed to lamb the previous season but lambed the following season.

Ewes failing to lamb in one season but lambing the following season had increases ranging from .08 to .45 in lambs born per ewe lambing than ewes lambing successively in both seasons (Table XX). This probably accounted for some of the slightly lower prolificacy (1.55)

TABLE XIX

BREEDING SEASON BY CYCLE INTERACTIONS FOR PROLIFICACY UNDER TWO CYCLES OF ACCELERATED LAMBING

	Breeding Season		
Cycle	Winter	Fall	Late-Spring
1	1.55 ± .04	1.81 ± .04	1.38 ± .06
	(214)[a]	(206)	(84)
2	1.78 ± .04	1.71 ± .06	1.31 ± .04
	(180)	(84)	(89)

[a]Number of ewes involved in the estimation are given in parentheses.

TABLE XX

SEASON BY SEASON COMPARISON OF PROLIFICACY FOR EWES THAT DID OR DID NOT LAMB THE PREVIOUS SEASON

Season of Lambing	Lambed Previous Season: No. of Ewes Lambing	Lambed Previous Season: No. of Lambs Born	Lambed Previous Season: Prolificacy	Open Previous Season: No. of Ewes Lambing	Open Previous Season: No. of Lambs Born	Open Previous Season: Prolificacy
Summer 76	160	243	1.52	55	92	1.67
Winter 77	198	358	1.81	9	17	1.89
Fall 77	79	107	1.35	5	9	1.80
Summer 78	72	122	1.69	107	200	1.87
Winter 79	78	133	1.71	8	15	1.88
Fall 79	66	86	1.30	32	44	1.38

resulting from winter 1976 breeding. Since only 38.5 percent of ewes lambed in the fall of 1977; prolificacy following this poor lambing was higher (1.78) when a majority of the ewes that failed to lamb in fall, 1977, had the opportunity to breed in winter to lamb in summer, 1978.

Prolificacy apparently was not affected as much by the alterations in the breeding season; at least not in the way the changes were manifested in the fertility data. Lambing seasons did not interact with breed of ewe effects for prolificacy.

The mean prolificacy averaged over breeds of ewe and over two cycles of accelerated lambing was 1.61 lambs. The 1/4Finn ewes were more prolific than 1/2D1/2R and 1/4D3/4R ewes under the system of lambing three times in two years.

Number of Lambs Born Per Ewe Exposed

This trait is a function of both fertility and prolificacy and represents an overall measure of reproductive performance. The results for this trait will therefore be presented here as an index of flock performance.

Least squares means for the five ewe groups for number of lambs born per ewe exposed averaged over the two cycles of accelerated lambing and over winter, fall and late-spring breeding seasons is presented in Table XXI. The 1/2D1/2R and 1/4Finns performed the same (1.31) for this trait and produced .14 more lambs than 1/4D3/4R under accelerated lambing.

Overall measure of reproductive efficiency was 1.28 over the six breeding seasons under accelerated lambing program. On per year basis this translates into 1.92 lambs born per year per ewe exposed. This

TABLE XXI

BREED OF EWE COMBINATION LEAST SQUARES MEANS FOR NUMBER OF LAMBS BORN PER EWE EXPOSED AVERAGED OVER TWO CYCLES AND THREE SEASONS OF ACCELERATED LAMBING

Breed of Ewe[1] Combination	n	Least Squares Means
1/2D1/2R	240	1.31 ± .05
1/4D3/4R	274	1.17 ± .05
1/4F1/2D1/4R	190	1.29 ± .06
1/4F1/4D1/2R	239	1.31 ± .05
1/4F3/4R	168	1.32 ± .05
1/4F[2]	597	1.31 ± .03
Overall Mean	1111	1.28 ± .02

[1]F = Finnsheep, D = Dorset and R = Rambouillet.

[2]Average over the three 1/4F groups.

figure came close to agreeing with 1.81 and 1.80 reported by Carter and Copenhaver (1973), in Dorset x Rambouillet and Suffolk x Rambouillet ewes, respectively, under two cycles of lambing three times in two years.

Significant breeding season by cycle least squares means ($P < .01$) were obtained for this trait. These least squares means are presented in Table XXII. Generally, for winter and fall breeding lambs born per ewe exposed, were higher than that obtained in the late-spring (averages over the two cycles were 1.53 and 1.58). For late-spring breeding, lambs born per ewe exposed, was low (.67 as an average over the two cycles). Lambs born per ewe exposed in largely a function of fertility effects.

Lambing to Conception Interval Under Accelerated Lambing

Under an accelerated lambing schedule of lambing every 242 days, with a gestation period of 147 days, ewes will have about 95 days after lambing before being bred for the next lambing. The purpose of this study is to investigate the lengths of the intervals from the average lambing date in one season to the average conception date in the following season when ewes are exposed every eight months.

The lambing to conception interval could only be measured on ewes that lambed in consecutive seasons. This interval is composed of two other intervals, namely, the interval from the average lambing date to the beginning of the next breeding season (hereafter called the recovery period); and the interval from the beginning of the breeding season to the average conception date. These intervals were measured on all ewes

TABLE XXII

BREEDING SEASON BY CYCLE LEAST SQUARES MEANS FOR NUMBER OF LAMBS BORN PER EWE EXPOSED UNDER TWO CYCLES OF ACCELERATED LAMBING

Cycle	Breeding Season		
	Winter	Fall	Late-Spring
1	1.47 ± .04	1.68 ± .05	0.53 ± .05
	(226)	(222)	(218)
2	1.58 ± .05	1.47 ± .08	0.81 ± .06
	(203)	(98)	(144)

[a]Number of ewes involved in the estimation are given in parentheses.

that lambed each season and together they will need to be less than or equal to 95 days if ewes are lambed every eight months. The sum of the two intervals as experienced under Oklahoma conditions will be presented first, then each one of the them will be discussed separately.

Both of these intervals are related to how readily ewes rebreed under an accelerated lambing program. The recovery period is a function of how early ewes lambed in the previous lambing season. The interval from the beginning of the breeding season to the average conception date is a function of the proportion of ewes cycling and conceiving during the breeding period proper.

Data used for these analysis started with May 15 - July 3 breeding for fall, 1975, lambing and continued on through to May 15 - June 30, 1979, breeding (refer to Table XII, Page 37). Fall, 1975, lambing was the last lambing season before the ewes were started on accelerated lambing program beginning with January-March, 1976, breeding.

The exact breeding dates and the seasons in which the ewes were lambed under accelerated lambing are presented in Table XXV. In cycle one, the ewes were bred at eight months intervals.

In cycle two, because of the poor fertility obtained in May-June, 1977 breeding in cycle one, which resulted in 38.5 percent ewes lambing in the fall, 1977 (refer to Table XIV); the winter, 1978, and fall, 1978, breeding seasons were advanced by 10 and 20 days, respectively. This was done to permit a longer interval from winter, 1979, lambing to late-spring, 1979, breeding.

The changes that were made are illustrated in Figure 3. The beginning of the breeding season, when rams were turned in for breeding are indicated with broken vertical lines. The lengths of each breeding

TABLE XXIV

SEASON BY CYCLE LEAST SQUARES MEANS FOR LAMBING TO CONCEPTION INTERVAL UNDER TWO CYCLES OF ACCELERATED LAMBING

Cycle	Breeding Season		
	Winter	Fall	Late Spring
1	86.5 ± 11.9[a]	101.2 ± 12.6	106.4 ± 16.3
	(159)[b]	(192)	(78)
2	76.1 ± 14.1	96.4 ± 13.6	112.9 ± 17.4
	(73)	(76)	(58)

[a]Interval ± standard deviations in days.

[b]Number of ewes involved in the estimation are given in parentheses.

TABLE XXV

BREEDING SEASON DATES AND LAMBING SEASONS UNDER TWO CYCLES OF ACCELERATED LAMBING

Cycle	Breeding Date	Lambing Season
1	January 15 - March 5, 1976	Summer 1976
1	September 15 - November 4, 1976	Winter 1977
1	May 15 - July 3, 1977	Fall 1977
2	January 5 - February 24, 1978	Summer 1978
2	August 25 - October 10, 1978	Winter 1979
2	May 15 - June 30, 1979	Fall 1979

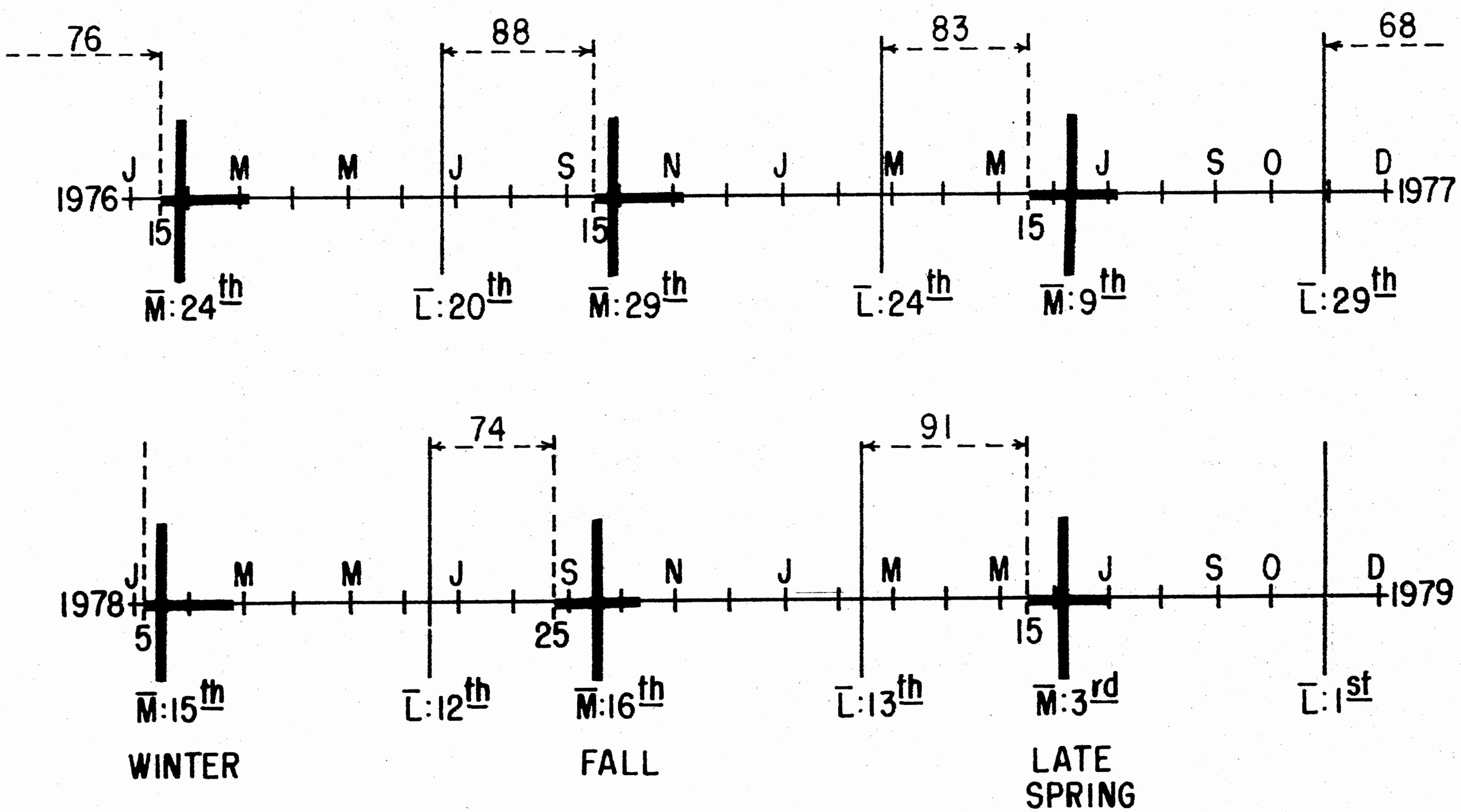

Figure 3. Accelerated Lambing Schedule Showing the Start of the Breeding Seasons (Broken Vertical Lines), Lengths of Winter, Fall and Late-Spring Breeding Seasons (Thick Horizontal Bars); Average Conception Dates ($\bar{M}$); Average Lambing Dates ($\bar{L}$), and the Recovery Periods Allowed From Average Lambing Dates to the Start of the Following Breeding Season

season are shown with thick horizontal bars. The average conception dates for all ewes that conceived ($\bar{M}$) and average lambing dates for all ewes that lambed ($\bar{L}$) in each season are also shown.

Lastly, in Figure 3, the lengths of the periods available for ewe recovery after each lambing season are indicated, i.e. from '$\bar{L}$' to the start of the next breeding period (shown by broken vertical lines). These recovery periods were calculated for all ewes that lambed in each season. It should be mentioned here that the average lambing date in the fall, 1975 lambing was on November 1, following a one-year interval from the previous lambing.

Data for the lambing to conception interval analyses came from all ewes that had consecutive lambings. The lambing date in one season was subtracted from the conception date following that lambing date. Analyses were performed on the intervals with actual dates of lambing of ewes being used as covariable. An analysis of variance table showing all sources of variation for lambing to conception interval is presented in the Appendix, Table XLI. Significant sources of variation present for lambing to conception intervals were: Season effects ($P<.01$) and Season by Cycle Interactions ($P<.05$).

Table XXIV shows a two-way table for the significant season by cycle least squares means for lambing to conception intervals. The interactions were probably partially caused by changes made in the breeding dates under accelerated lambing and partly due to the time of year within which ewes are lambed.

In attempting to find possible causes to explain the interactions documented in Table XXIV and illustrated in Figure 3, the proportion of ewes that mated and the proportion that conceived to matings in the first 17 days were found from the mating records. These are presented in Table XXV. The proportion of ewes that mated in two or more 17-day cycles were also found. These are shown in Table XXVI. The two tables (XXV and XXVI) together with Figure 3 will be used in the discussion of the intervals with respect to the three breeding seasons--winter, fall and late-spring.

The average lambing dates and average conception dates shown in Figure 3 were calculated, respectively, based on all ewes that lambed and on all ewes that conceived each season. Similarly, the lengths of the intervals from the start of the breeding season to the average conception date and the proportion of ewes mating and conceiving in the first 17 days, shown in Table XXV, were calculated based on all ewes conceiving each breeding season. The lengths of the lambing to conception intervals and their accompanying standard deviations, presented in Table XXV were, however, calculated based only on ewes that lambed in successive seasons.

Winter Breeding

The lengths of the intervals after fall lambing to the next conception in winter appeared to be the shortest, 86.5 and 76.1 days, respectively, in cycles one and two (Table XXIV). In both cycles, the intervals following fall lambing were shorter than 95 days.

The recovery period following fall, 1975, average lambing date (November 1, 1975) was 76 days (Figure 3) and fertility obtained in January, 1976, breeding was 92.8 percent. In cycle two, when the winter breeding season was shortened by 10 days, the length of the recovery period was decreased by eight days, compared to that in cycle one.

TABLE XXV

INTERVAL FROM THE START OF THE BREEDING SEASON TO THE AVERAGE CONCEPTION DATE AND THE PROPORTION OF EWES MATING AND CONCEIVING TO FIRST 17 DAYS MATINGS UNDER TWO CYCLES OF ACCELERATED LAMBING

Cycle	Breeding Season	Winter	Fall	Late-Spring
1	Interval, start of breeding to average conception date	9	14	25
	Proportion of ewes mating in first 17 days	91.2	96.8	46.6
	Proportion of ewes conceiving to first 17 days' matings	74.3	55.4	17.2
2	Interval, start of breeding to average conception date	10	22	19
	Proportion of ewes mating in first 17 days	88.3	84.3	37.8
	Proportion of ewes conceiving to first 17 days' matings	77.2	28.0	20.2

TABLE XXVI

PROPORTION OF EWES THAT MATED IN THE FIRST 17 DAYS, PROPORTION MATING IN TWO OR MORE 17-DAY CYCLES AND PROPORTION THAT FAILED TO MATE AT ALL UNDER TWO CYCLES OF ACCELERATED LAMBING

Breeding Season	Winter Jan.-March 1976	Winter Jan.-Feb. 1978	Fall Sept.-Nov. 1976	Fall Aug.-Oct. 1978	Late-Spring May-June 1977	Late-Spring May-June 1979
Number of Ewes Exposed	226	206	222	198	221	193
First 17 Days Cycle						
Number of ewes that mated	206	182	215	167	103	73
Percent of ewes that mated	91%	88%	97%	84%	47%	38%
Two or More 17-Day Cycles						
Number of ewes that mated[a]	55	37	111	136	138	117
Percent of ewes that mated	24%	18%	52%	69%	62%	61%
Ewes that did not mate at all	---	1	---	---	43	30
Percent of ewes that did not mate	---	---	---	---	19%	16%

[a]Does not include ewes that conceived in the first 17 days.

Fertility recorded to January, 1978, breeding was 85.7 percent.

In winter, the interval after the start of the breeding to the average conception date, in cycle one, was nine days (Table XXV). There were 91.2 percent of ewes mating out of which 74.3 percent became pregnant. In cycle two the interval was 10 days and 88.3 percent ewes mated in the first 17 days. A high proportion of ewes (77.2%) were pregnant to first 17 days' matings. It appears shortening the interval from fall lambing to the start of winter breeding in cycle two by 10 days did not have any appreciable effect on the proportion of ewes that conceived. There were about three percent more ewes pregnant in cycle two than in cycle one, winter breeding.

The proportion of ewes that mated in the first 17 days and the proportion that mated in two or more 17-day cycles are presented in Table XXVI. In winter breeding, in both cycles one and two, there were 91 and 88 percent ewes mating in the first 17 days. This is an indication that a high proportion of ewes cycled and conceived in the first 17 days and therefore there were few matings in the other 17-day cycles.

It was the desire in this study to obtain one estimate of the length of the interval from lambing in one season to conception in the next season. The estimates shown in Table XXIV were, therefore, pooled even though there were interactions partly caused by management decisions and partly caused by the seasonal restriction to breeding of sheep. The mean interval from fall average lambing date to winter average conception date was found to be 84 days. It appears the interval following fall lambing is not a problem interval.

Mauléon and Dauzier (1965) and Hunter (1968) reported that when ewes lambed in September-November, that the seasonal anestrus did not prolong the post-partum interval and a lot of ewes returned to estrus quickly to be rebred. There was evidence, in this study, to show that after fall lambing a high proportion of ewes did cycle readily and were rebred. Changes made in the winter breeding dates did not affect the proportion of ewes that became pregnant very much, if any.

Fall Breeding

The intervals from average summer lambing date to average fall conception date (Table XXIV), in the two cycles, were intermediate between the intervals preceding winter breeding and that preceding late-spring breeding. They were 101.2 days, in cycle one and 96.4 days, in cycle two.

After lambing in June, 1976, in cycle one, ewes had 88 days to recover (Figure 3). Fertility recorded in fall, 1976, breeding was 94.7 percent. In cycle two, the breeding season was advanced by 20 days. This shortened the recovery period by 14 days, and the proportion of ewes conceiving to fall, 1978, breeding was 88.7 percent, that is, 6 percent decrease in fertility compared to that obtained in cycle one.

The interval after the start of the fall breeding to average conception date was 14 days in cycle one (Table XXV). There were 96.8 percent ewes mating in the first 17 days and 55.4 percent ewes conceiving within the same period. In cycle two, the results were biased by epididymitis. Even with the 20 days advance in the breeding season, the average conception date was delayed by eight days. There were 12.5 percent fewer ewes mating in the first 17 days and only 28 percent conceiving within the same 17 days.

It was discovered at the time of lambing that fall 1978 breeding was affected by ram epididymitis which caused infertilities in the ewe flock. A comparison of the proportion of ewes mating in the two fall seasons (1976 and 1978) is presented in Table XXVI. In the first 17 days, 97 and 84 percent ewes mated in cycles one and two, respectively. There were 17 percent more ewes mating in cycle two over cycle one, in two or more 17-day cycles, yet fewer proportion of ewes conceived to these matings in cycle two (55 vs. 28%). This is an indication that even though more ewes mated in two or more cycles, they failed to settle probably as a result of the ram epididymitis. Epididymitis will not cause a decrease in the proportion of ewes mating in the first 17 days, but it, definitely, will cause a decrease in the proportion of ewes conceiving to matings in the first 17 days. This effect was quite obvious in Table XXV.

The mean length of the interval after lambing in the summer, June, to the average conception date in the fall, September, was estimated to be 99 days. It was 15 days longer than the interval preceding the winter breeding. This interval was intermediate in length between the interval preceding winter breeding (84 days) and that preceding the late-spring breeding (109 days).

Conception rates in the first 17 days in the winter breeding are generally higher than conception rates in the first 17 days in the fall breeding. Shelton and Morrow (1965) investigated the effect of season of year on overall reproductive efficiency of mature Rambouillet sheep. They found the highest ovulation rate occurring at September mating, while the highest lambing rate followed December mating. They suggested that the length of the photoperiod was the major factor affecting the occurrence of estrus and ovulation rate, but suggested that lambing results particularly at the September mating period may have been substantially modified by high environmental temperatures.

Changes in the breeding dates in the fall due to management decisions and also disease problems, decreased the proportion of ewes that conceived in the first 17 days of breeding in cycle two. Considering a much longer breeding period, however, winter and fall fertilities were similar (92.8 and 85.7 vs. 94.7 and 88.7) in cycles one and two, respectively.

Late-Spring Breeding

The estimates of the intervals from average winter lambing date to average late-spring conception date were the longest in all three periods. They were 106.4 and 112.9 days, respectively in cycles one and two (Table XXIV).

Lambing occurred in cycle one on February 24, 1977, prior to the late-spring breeding. The recovery period after this early lambing was 83 days (Figure 3) and fertility to late-spring, 1977, breeding was 38.5 percent. The 10 and 20 days advances in the winter and fall breeding periods in cycle two were to allow more recovery time from the winter, 1979, lambing to the beginning of late-spring, 1979, breeding, because of the poor fertility in late-spring, 1977 breeding. The recovery period obtained, after the adjustment, was 8 days longer than that in cycle one and fertility recorded in late-spring, 1979, breeding was 61.8 percent, that is, 22.3 percent higher ($P<.01$) than in cycle one.

In the late-spring in cycle one, the average conception date occurred 25 days after the breeding season started (Table XXV). The average conception date was delayed by 16 days when compared to that in the winter breeding season, and 11 days when compared to that in the fall breeding season. There were 46.6 percent ewes mating and 17.2 percent ewes conceiving in the first 17 days. This shows the low sexual activity in the late-spring breeding season. In cycle two, the interval from the start of breeding to the average conception date was 19 days, even though a longer recovery period had been allowed (91 days). Fewer ewes (37.8%) mated in the first 17 days, but 3 percent more conceived within the same period, over that in cycle one.

There were fewer ewes mating in the first 17 days in the late-spring (46.6 and 37.8%) compared to the proportions that mated in winter and fall breeding seasons in the same 17 days, see Table XXVI for the comparisons. There were more ewes mating in two or more 17-day cycles (62 and 61%), but the proportion that conceived during the late-spring breeding seasons were very small (17.2 and 20.2%, Table XXV). Shelton and Morrow (1965) suggested that lambing results from June breeding period may be substantially modified by environmental temperatures. About 19 and 16 percent of the ewes also failed to mate at all during the entire late-spring breeding season. These mating results show the low sexual activity of ewes when they are bred at this time of the year.

Studies involving breeding late in the spring (Mauléon and Dauzier, 1965; Hunter, 1968; Whiteman et al., 1972; and Walton and Robertson, 1974) have suggested that ewes lambing early in the year do not readily resume cycling for remating. Findings in this study agree with these suggestions.

The length of the mean interval from winter average lambing date to late-spring average conception date was found to be 109 days. This was 25 days longer than the interval preceding winter breeding and was 10 days longer than the interval preceding the fall breeding. Eyal et al. (1973) found the interval following winter lambing to be longer than intervals following summer and fall lambings.

The discussion thus far has been concerned with estimates using different bases of ewes. For example, the average lambing dates were estimated using all ewes that lambed and the average conception dates were also estimated using all ewes that conceived in each season. The lambing to conception intervals, however, were estimated only on ewes that lambed in consecutive seasons (see illustration in Figure 3). There was a concern to determine whether or not an ewe lambing in succession will have any effect on the average conception date, and also to determine whether or not the date of lambing of a particular ewe has any effect on the average conception date.

In order to study these two things, two separate analyses were performed. First the average conception dates of ewes that lambed continuously in two successive seasons were found and compared to the average conception dates of their contemporaries that did not lamb the previous season but lambed the following season. Secondly, the interval from lambing to conception was regressed on the lambing dates of ewes lambing in consecutive seasons.

The results from the first analysis are summarized in Table XXVII. Ewes that lambed in two consecutive seasons usually had their average conception dates occurring on or about the same date as the conception dates of ewes that were open the previous season. In only two breeding

TABLE XXVII

SEASON BY SEASON COMPARISON OF AVERAGE CONCEPTION DATE FOR EWES THAT DID OR DID NOT LAMB THE PREVIOUS SEASON

Season of Breeding	Lambed Previous Season		Open Previous Season	
	No.	Conception Date	No.	Conception Date
Winter 76	160	24	55 (58)[a]	24
Fall 76	198	271	9 (10)	271
Late-Spring 77	79	158	5 (13)	151
Winter 78	72	16	107 (120)	14
Fall 78[b]	96	257	8 (20)	265
Late-Spring 79[b]	66	154	36 (90)	153

[a]Numbers in parentheses represent total number of ewes open.

[b]Fall 1978 and Late-Spring 1979 breeding were affected by epididymitis to an unknown extent.

seasons did there show differences greater than two days. In the late-spring, 1977, breeding season ewes that were open the previous season had their average conception date occurring seven days earlier than ewes that lambed the previous season, and in fall, 1978, the average conception date of ewes open was delayed by eight days. These deviations were probably due to chance.

Of particular interest in Table XXVII, are the number of ewes that failed to lamb each season (shown in parentheses). A greater number of ewes failed to lamb in the fall seasons (58 in fall 1975, and 120 in fall 1977). A large number of ewes (90) failed to lamb in winter 1979, but this was as a result of ram epididymitis which was noted in winter, 1979, and fall, 1979, lambing results (see also Tables XXV and XXVI and their accompanying discussions). The epididymitis caused the number of ewes lambing successively in these two seasons to be few (66).

Differences in the average conception dates of ewes that lambed in successive seasons and in the average conception dates of ewes that were open in one season but lambed in the next season were not significant.

The regression coefficients of the length of the interval on actual lambing dates of ewes obtained from the regression analyses are shown in Table XXVIII. All three coefficients were near -1 which indicates that regardless of when the ewes lamb they all breed back at about the same time. None of these regression coefficients were significantly different from -1 ($P>.05$). This implies that time of lambing date did not have any effect on the average conception date.

There were distinctly different interval lengths ($P<.01$) following lambings in February, October and June for the five kinds of ewes used under accelerated lambing program. With approximately eight months

TABLE XXVIII

REGRESSION COEFFICIENTS OF INTERVAL ON LAMBING DATE AND THEIR STANDARD ERRORS IN THE THREE LAMBING TO CONCEPTION PERIODS UNDER ACCELERATED LAMBING

Period Lambing - Conception	Regression Coefficients ± Standard Errors, for Lambing Date
Fall - Winter	- .91 ± .05
Summer - Fall	- .95 ± .11
Winter - Late Spring	-1.02 ± .08

between lambings, the interval following February lambing was the longest (109 days). After lambing in October the interval to the next conception was the shortest (84 days). Following June lambing the interval to the next conception was intermediate (99 days). These results are in very good agreement with other literature reports.

The rebreeding performance of ewes after February lambing was generally poor. This is in agreement with the cyclical nature of sheep which indicates seasonal anestrus as a factor prolonging the post-partum interval after lambing very early in the year. After lambing in October, the interval to the next conception is not a problem interval and most ewes readily rebreed within the first 17 days of the breeding season. Conception rate, in the first 17 days, following June lambing was a lot lower than conception rate following October lambing because of the epididymitis problem which biased the winter lambing results. There appeared to be differences of about 10 days between each of the three interval estimates obtained.

All five kinds of ewes used in the study performed similarly every season. Even with the 10-day differences in intervals there existed considerable differences ($P<.01$) in conception rates. Conception rates in the winter and fall breeding seasons (for June and February lambings) were high and similar when averaged over the two cycles of accelerated lambing (89.3 and 91.7%), while conception rate in the late-spring breeding season (for October lambing) was poor (50.2%).

Repeatability Estimates for Number of Lambs Born

Repeatability of number of lambs born in sheep has been estimated in two ways: Either through the classical intra-class correlation method, or through the regression of subsequent on early performance. The latter method allows for the difference in subsequent performance associated with changes of one lamb in early performance to be estimated through the regression coefficient.

The objective of this study was to estimate the repeatability of number of lambs born in the ewe flock and to use the estimates of repeatability to predict the lifetime performance of these crossbred ewes under Oklahoma conditions.

Records on 263 crossbred ewes produced in two replicates in 1971 and 1972 were used for this study. After the project was terminated in the fall of 1979 some of these ewes had had 10 lambing opportunities and some had 11 opportunities (refer to Table XIII). The data were analyzed in two ways: Intra-class correlation method of estimating repeatability; and the regression of subsequent lambings on the first and on the second lambing classes.

The estimates of repeatability by the intra-class correlation method using the variance component estimation procedure are shown in Table XXIX. The estimates of various components for the five breed combinations ranged from .177 for 1/4F1/4D1/2R to .090 for 1/4F3/4R; and they were not significantly different from zero ($P>.05$). A pooled overall breed combination estimate of .138 was obtained and it was significantly different from zero ($P<.05$).

Only one replicate of 33 ewes in the 1/4F3/4R group were produced in 1972. The rest of all other breed groups of ewes were in two replicates produced in 1971 and 1972 (numbers produced in each breed group are given in Table XI). The production records indicated that the 1/4F3/4R group started production, in terms of number of lambs born,

TABLE XXIX

BETWEEN AND WITHIN EWES COMPONENTS OF VARIANCE FOR FIVE BREEDS OF EWE COMBINATIONS BY THE VARIANCE COMPONENT ESTIMATION PROCEDURE, AND INTRA-CLASS CORRELATION ESTIMATES OF REPEATABILITY

Breed of Ewe Combinations[1]	1/2D1/2R	1/4D3/4R	1/4F1/2D1/4R	1/4F1/4D1/2R	1/4F3/4R	Pooled Over All Breed Combinations
Variance Component						
Var (Ewes)	.0696	.0722	.0906	.1050	.0486	.0823
Var (Error)	.4548	.4563	.5418	.4884	.4934	.5142
Repeatability Estimate by Intra-Class Correlation						
Lambs Born	.132 ± .144	.137 ± .139	.143 ± .149	.177 ± .147	.090 ± .180	.138 ± .067

[1]F = Finnsheep, D = Dorset and R = Rambouillet.

rather slowly. They were slow to mature compared to the other groups. Probably their slow maturity coupled with the few numbers produced, were the causes for the low repeatability estimate (.090).

The overall estimate of .138 for repeatability by intra-class correlation compared favourably with .13 reported by Fogarty et al. (1976) in 1-10 year old Australian Border Leicester ewes. The estimate was close to .12 reported by Rae and Ch'ang (1955) in 2-7 year old New Zealand Romneys; close to .11 reported by Inskeep et al. (1976) for various breeds, whose ages ranged from 2-4 years, in the United States. The estimate was also close to .11 reported by Radomska et al. (1976) for 1-4 year old Polish Romney Marshes.

Regression of subsequent lambing on early performance was done in two ways: First, the regression of all later lambings (excluding the first) on the initial lambing classes which were 0, 1 and 2. Secondly, the regression of all lambings (excluding the first and second lambings) on the second lambing classes which were 0, 1, 2 and 3. Estimates of repeatability from these two methods are presented in Table XXX.

Repeatability estimates for the ewe combinations based on initial lambing classes range from .071 for 1/4F1/2D1/4R to .198 for 1/4F1/4D1/2R. The estimate of .071 for 1/4F1/2D1/4R group was not significantly different from zero ($P>.05$). The estimates for the four other breed groups were significantly different from zero ($P<.05$). The pooled estimate of repeatability based on initial lambing classes was .121 lambs born per ewe season and was significantly different from zero, $P<.01$.

The pooled estimate of .121 was in good agreement with an estimate of .12 reported by Fogarty et al. (1976) in 1-10 years old Australian Border Leicester ewes. The estimate obtained in this study was close

TABLE XXX

ESTIMATES OF REPEATABILITY FOR NUMBER OF LAMBS BORN BASED ON INITIAL AND SECOND LAMBING CLASSES

Breed of Ewe Combinations[1]	Based on Initial Lambing Classes		Based on Second Lambing Classes	
	Number of Ewes	Repeatability Estimate ± Standard Error	Number of Ewes	Repeatability Estimate ± Standard Error
1/2D1/2R	51	.101 ± .047	50	.025 ± .042
1/4D3/4R	55	.085 ± .048	54	.042 ± .041
1/4F1/2D1/4R	48	.071 ± .070	45	.144 ± .049
1/4F1/4D1/2R	49	.198 ± .058	49	.134 ± .050
1/4F3/4R	34	.161 ± .071	33	-.097 ± .057
Pooled Over All Breed Combinations	237	.121 ± .025	231	.046 ± .020

[1]F = Finnsheep, D = Dorset and R = Rambouillet.

to an estimate of .10 obtained by Young et al. (1963) in 2-7 year old Australian Merinos; and an estimate of .14 obtained by Forrest and Bichard (1974) in 1-10 year old British Clun Forest ewes.

Estimates of repeatability obtained based on the second lambing classes range from -.097 for 1/4F3/4R to .144 for 1/4F1/2D1/4R. The estimates reported for 1/4F3/4R (-.097), 1/2D1/2R (.025) and 1/4D3/4R (.042) were not significantly different from zero (P>.05). The estimate of .144 reported for 1/4F1/2D1/4R was significantly different from zero (P<.001) and .134 for 1/4F1/4D1/2R was significantly different from zero (P<.01). The pooled estimate of repeatability based on second lambing classes was .046 lambs born per ewe season and significantly different from zero (P<.01).

All estimates of repeatability based on second lambing classes were positive, except for -.097 for 1/4F3/4R. The negative estimate was probably due to the few number of ewes produced in this breed group. The pooled estimate based on second lambing classes was very low (.046) compared to other estimates reported in the literature, or to estimates obtained in this study by the regression of subsequent on initial lambing (.121) or intra-class correlation (.138).

Bowstead (1930) Briggs (1936) and Longrigg (1961) have shown that ewes bred as lambs have a higher lifetime lamb production than when breeding is delayed until yearling age. Ewes in this study were bred when they were about seven months old to lamb for the first time at one year of age. Hulet, Wiggins and Ercanbrack (1969) found that cumulative lamb production was without exception greater for ewes which showed estrus as lambs than for those which did not.

From the results of the regression of subsequent on early performance, if ewes producing twin lambs were to be selected over ewes producing no lambs at their initial lambing, by the ninth year, the twin-bearer ewes would be expected to produce 2.18 more lambs over ewes bearing no lambs. Similarly, if ewes bearing twins or triplets were selected, based on their second lambing, they would be expected to produce .83 more lambs over ewes bearing no lambs.

Subsequent mean number of lambs born per season based on number produced at one year of age (0, 1 and 2) and at two years of age (0, 1, 2 and 3) were found from the regression method. The means are shown by breed of ewe groups in Tables XXXI and XXXII, respectively. The pooled over all breed groups in the various classes, are shown at the foot of each column. Of particular importance are the differences between the classes 0 and 1, 1 and 2, and additionally 2 and 3 in Table XXXII.

The differences obtained between classes 0 and 1 and between classes 1 and 2, in the pooled subsequent mean based on initial lambing classes (Table XXXI) were: .16 and .11, respectively. The means for the classes 0, 1 and 2 from which these values were calculated were: 1.33, 1.49 and 1.60, respectively.

Smirnov (1935) found a difference of .26 between groups that bore singles and those that bore twins initially and a difference of .53 between those that bore twins and those that bore triplets initially in the Romanov sheep. Young et al. (1963) found a difference of .08 between barren ewes and single bearing ewes and .16 between single and twin bearing ewes based on their initial lambing in Merino ewes. Fogarty et al. (1976) reported .22 fewer lambs produced by Border Leicester ewes failing to lamb initially.

Roeper (1960) and Van den Bosch (1965), in Texel ewes divided into

TABLE XXXI

MEAN NUMBER OF LAMBS BORN PER SUBSEQUENT SEASON BASED ON INITIAL LAMBING CLASSES FOR THE BREED OF EWE COMBINATIONS

Breed of Ewe Combinations[a]	Lamb Class = 1st Lambing			Mean Number of Lambs Born
	0	1	2	
1/2D1/2R	1.45 ± .05 (229)[b]	1.49 ± .04 (362)	1.79 ± .08 (71)	1.51 ± .03 (662)
1/4D3/4R	1.23 ± .04 (332)	1.41 ± .04 (306)	1.31 ± .10 (48)	1.32 ± .03 (686)
1/4F1/2D1/4R	1.48 ± .07 (120)	1.50 ± .04 (401)	1.51 ± .11 (39)	1.50 ± .03 (560)
1/4F1/4D1/2R	1.27 ± .07 (118)	1.51 ± .03 (448)	1.69 ± .07 (91)	1.49 ± .03 (657)
1/4F3/4R	1.32 ± .05 (203)	1.57 ± .05 (203)	1.13 ± .25 (8)	1.44 ± .04 (414)
Pooled Over All Breed Combinations	1.33 ± .02 (1002)	1.49 ± .02 (1720)	1.60 ± .05 (257)	1.45 ± .01 (2979)

[a]F = Finnsheep, D = Dorset and R = Rambouillet.

[b]Number of lambing opportunities involved in the estimation are given in parentheses.

TABLE XXXII

MEAN NUMBER OF LAMBS BORN PER SUBSEQUENT SEASON BASED ON SECOND LAMBING CLASSES FOR THE BREED OF EWE COMBINATIONS

Breed of Ewe Combinations[a]	Lamb Class = 2nd Lambing				Mean Number of Lambs Born
	0	1	2	3	
1/2D1/2R	1.37 ± .08	1.54 ± .05	1.46 ± .04	1.62 ± .13	1.49 ± .03
	(73)[b]	(222)	(259)	(26)	(580)
1/4D3/4R	1.39 ± .06	1.22 ± .04	1.31 ± .04	1.20 ± .21	1.29 ± .03
	(123)	(216)	(253)	(10)	(602)
1/4F1/2D1/4R	1.20 ± .08	1.48 ± .07	1.53 ± .04	1.65 ± .15	1.47 ± .03
	(76)	(91)	(288)	(23)	(478)
1/4F1/4D1/2R	1.12 ± .09	1.49 ± .05	1.57 ± .04	----	1.49 ± .03
	(65)	(234)	(282)	(--)	(581)
1/4F3/4R	1.62 ± .07	1.37 ± .05	1.46 ± .07	----	1.46 ± .04
	(86)	(175)	(106)	(--)	(367)
Pooled Over all Breed Combinations	1.36 ± .04	1.42 ± .03	1.47 ± .02	1.56 ± .10	1.44 ± .02
	(423)	(938)	(1188)	(59)	(2608)

[a]F = Finnsheep, D = Dorset and R = Rambouillet.

[b]Number of lambing opportunities involved in the estimation are given in parentheses.

single and twin bearer groups based on their first lambing at one year old, showed consistently positive increases ranging from .06 to .17 lamb in the twin bearer group from their second lambing to the fifth lambing (refer to Table X). Their records indicated that a selection difference of one lamb at first lambing showed a marked effect on the number of lambs produced in the years that followed.

The results of subsequent means based on the ewes' first lambing showed an overall difference of .11 more lamb between the single bearer group and the twin bearer group, in this study. It is possible for total production level to be increased if the production levels of ewes giving births to twins and triplets at their initial lambing could be followed and flock replacements chosen from their offspring.

Subsequent mean number of lambs born based on the second lambing classes are shown in Table XXXII. The pooled over all breed subsequent mean for the classes 0, 1, 2 and 3 were: 1.36; 1.42; 1.47 and 1.56, respectively. The differences obtained between classes 0 and 1, 1 and 2; and 2 and 3 in subsequent means were: .06, .05 and .09, respectively. These differences were lower than the same differences (i.e., between 0 and 1 and 1 and 2 classes) based on the first lambing classes (.06 vs. .16 and .05 vs. .11, respectively).

Even though positive differences in the means based on their second lambing classes were obtained, these differences were all about the same magnitude (i.e., .06, .05 and .09). The number of lambing opportunities (in parentheses in the tables) available in class 3, were so few. These lambing opportunities were 26, 10, and 23 for 1/2D1/2R, 1/4D3/4R and 1/4F1/2D1/4R, respectively. Moreover, two breed groups 1/4F1/2D1/4R and 1/4F3/4R, produced no triplets at their second lambing.

The 1/4F3/4R were noted earlier to be slow in maturing. There were also few ewes produced in this group. Maybe these facts and the fact that no triplets were produced at their second lambing, contributed to the negative repeatability estimate (-.097) obtained for this group based on their second lambing classes.

Good estimates of repeatability were reported by Turner et al. (1958 and 1962) in a two may selection for multiple births versus single births in five and six year old Merinos. For six subsequent lambings, the multiple bearer ewes (in each of the 2 years) averaged 31 more lambs per 100 ewes mated than the single bearer ewes. Unselected daughters of the base ewes, ranging from 2 to 6 years of age, also averaged 21 more lambs per 100 ewes mated for the multiple bearer group. By the age of 6 years, the multiple-bearer unselected daughters were showing 31 more lambs per 100 ewes mated.

Turner et al. (1958 and 1962) pointed out the fact that there was evidence to indicate that twinning performance at initial lambings could be an indicator of subsequent performance; even though the ewes they used were five and six years old at their initial lambing.

Young et al. (1963) were able to show in Merinos that the difference between 1 and 2 lambs born was more repeatable than the difference between 0 and 1 lamb. The results from this study in Oklahoma show the opposite. The greater difference in subsequent performance between ewes bearing 2 or 1 lambs initially, compared with those bearing 1 or 0, led Young et al. (1963) to suggest that selection for multiple births would be more profitable than selection against failure to lamb.

A common practice is to cull ewes for failure to lamb, either at their first lambing, any lambing or any two lambings in succession. In a flock which obtains its replacements from an outside source, Yalcin and Bichard (1964) have shown that where reproductive performance increases markedly with age and the repeatability of the culling criterion is low, the superior performance of those ewes that survive culling is outweighed by the relatively poor performance of the increased proportion of younger ewes entering the flock. Overall flock performance is consequently reduced.

In view of the general findings that the reproductive performance in ewes increases with age, but that the repeatability of the trait is low, if selection for the proportion of ewes lambing initially (or against its complement, ewes failing) were practiced, it probably would not lead to any spectacular results, if one's own replacements are not kept. For example, in Turner's (1969) review, she recommended the culling of ewes that failed to produce multiple births as a means of increasing the incidence of multiple births in the "current flock". However, despite the relatively small age effects on reproductive performance in the Merino, her theoretical considerations showed that the gain following culling was almost vitiated by the consequent alteration in flock structure.

Based on the findings on initial lambing, if those ewes that failed to lamb were culled, 35.4 percent (93 ewes) of the total flock of 263 ewes would have been culled. It would therefore be proper to suggest a system of identifying the multiple bearer ewes and then follow their production in the flock. Those that failed to lamb initially could be identified differently and if they failed a second time, culling them would be in order. However, advantages and disadvantages of culling should always be considered.

CHAPTER V

SUMMARY

The reproductive performance of 263 crossbred ewes representing five combinations of Finnsheep (F), Dorset (D) and Rambouillet (R) breeding were evaluated under two cycles of accelerated lambing i.e., lambing every eight months. The five breed combinations represented were: 1/2D1/2R; 1/4D3/4R; 1/4F1/2D1/4R; 1/4F1/4D1/2R; and 1/4F3/4R with the last three groups combined as 1/4Finns. They were four and five years old when put on accelerated lambing. Ewes were mated to yearling Hampshire and Suffolk rams and their reciprocal crosses each season. Each cycle was made up of three lambing seasons. Summer, winter and fall, with their respective breeding dates being in January-February, September-October and May-June.

Reproductive performance averaged over the two cycles show May-June breeding resulting in a low (50%) fertility, when compared to fertility in January-February (92%) or September-October (89%) breeding. There were class of ram (purebred or crossbred) by season of breeding interactions for fertility ($P<.05$). Fertility to pure- and crossbred rams were high and similar in winter and fall breeding seasons and ranged from 89 to 93%. Crossbred rams produced 21% more lambs than purebred rams when breeding in May-June. Fertility levels of 1/2D1/2R and 1/4D3/4R ewe groups were similar when they were bred in the winter and fall seasons and ranged from 87 to 94%. In the late-

spring breeding season 1/2D1/2R were more fertile than all other groups (67 vs. 47%). There was a suggestion that the 1/4Finns were about 5% higher in fertility when they are bred during January-February than the other groups.

Lambs born per ewe lambing, averaged over the two cycles was high when ewes were bred in the winter (1.67) and in the fall (1.76) and low when ewes were bred in the late-spring (1.35). The 1/4Finn ewes produced .10 and .16 more lambs than 1/2D1/2R and 1/4D3/4R, respectively.

Under accelerated lambing, the intervals from average lambing date in one season to average conception date in the next season were also evaluated. The interval was measured on ewes which lambed in successive seasons. The actual dates when the rams were turned in for breeding in the two cycles were different. Breeding dates for winter and fall in cycle two were advanced by 10 and 20 days, respectively. The mean interval following winter (February) lambing was found to be the longest (109 days). After summer lambing (June) the interval to the next conception was intermediate (99 days) but this results was biased upwards by epididymitis. Following fall (October) lambing the interval to the next conception was the shortest (84 days). There was an indication that after lambing in winter (February) ewes do not readily rebreed. When ewes do lamb in the fall (October) they readily resume cycling for remating. After summer (June) lambing about 55 percent of the ewes will rebreed in the first 17 days.

Part of the study involved the estimation of repeatabilities of number of lambs born using all data available on the crossbred ewes since their production in 1971 and 1972. Repeatability of number of lambs born estimated by intra-class correlation method was found to be

.138 ± .067. Repeatability of number of lambs born estimated by the regression of subsequent lambing on initial lambing classes was found to be .121 ± .025 lambs born per ewe season; and subsequent lambing on second lambing classes was found to be .046 ± .020 lambs born per ewe season. Ewes producing twins at their first lambing raised .11 more lambs than single bearer ewes and single bearer ewes raised .16 more lambs than ewes producing no lambs, throughout their lifetime. Based on their second lambing, ewes producing triplets raised .09 more lambs than ewes producing twins. Twin-bearer ewes raised .05 more lambs than single-bearer ewes and single bearer ewes raised .06 more lambs than ewes producing no lambs.

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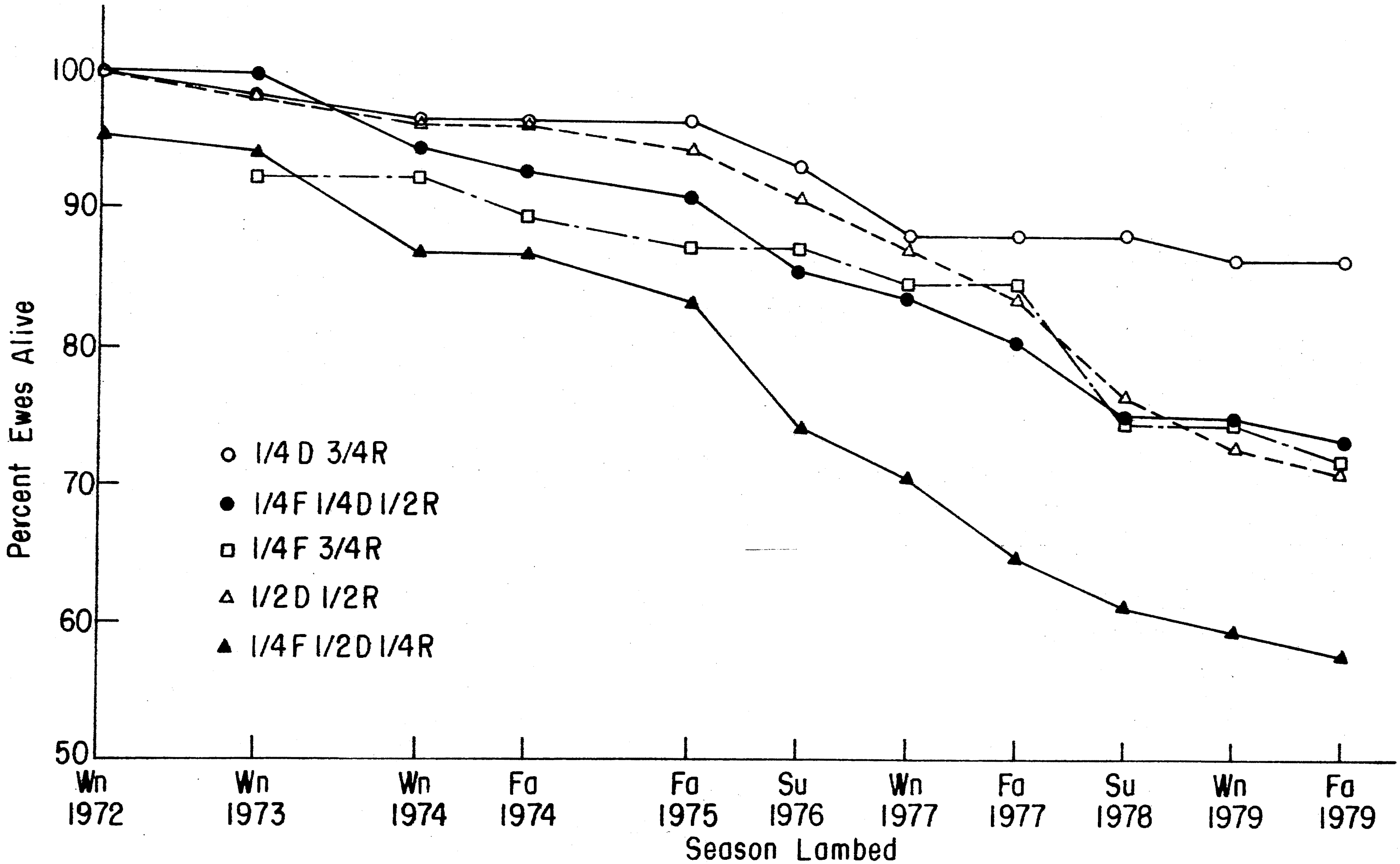

Figure 4. Longevity of Ewe Groups

TABLE XXXIII

LONGEVITY OF EWE GROUPS

Breed of Ewe Combinations[a]	Winter 1972	Winter 1973	Winter 1974	Fall 1974	Fall 1975	Summer 1976[b]	Winter 1977	Fall 1977	Summer 1978	Winter 1979	Fall 1979	Original Number of Ewes
1/2D1/2R	26	54	53	53	52	50	48	46	42	40	39	55 (26)[c]
1/4D3/4R	28	58	57	57	57	55	52	52	52	51	51	59 (28)
1/4F1/2D1/4R	23	51	47	47	45	40	38	35	33	32	31	54 (24)
1/4F1/4D1/2R	22	56	53	52	51	48	47	45	42	42	41	56 (22)
1/4F3/4R		36	36	35	34	34	33	33	29	29	28	39 (O)
Sum Over Breed Combinations	99	255	246	244	239	227	218	211	198	194	192	263 (100)
Percent Alive	99	97.0	93.5	92.8	90.9	86.3	82.9	80.2	75.3	73.8	72.2	
Percent Alive Under Accelerated Lambing						100	96.0	93.0	87.2	85.5	83.7	

[a]F = Finnsheep, D = Dorset and R = Rambouillet.

[b]Accelerated lambing was started with the Summer 1976 lambing.

[c]Numbers in parentheses were the total number of ewes produced in 1971.

TABLE XXXIV

ANALYSES OF VARIANCE FOR FERTILITY AND PROLIFICACY

Source of Variation	Fertility		Prolificacy	
	d.f.	Mean Square	d.f.	Mean Square
Breed of Ewe Combination (BOE)	4	.2063	4	3.0763**
Breed of Ram (BOR)	3	.5582*	3	.3674
Season	2	23.0390	2	17.2988
Cycle	1	.3288	1	.8834
Season x Cycle	2	2.4344**	2	3.8590**
Season x BOE	8	.2890	8	.8714
Season x BOR	6	.4472*	-	---
Season x Cycle x BOE x BOR	47	.1549	49	.5745
Residual	1037	.1245	1339	.2992

*Significant at P < .05.

**Significant at P < .01.

TABLE XXXV

BREED OF RAM LEAST SQUARES MEANS FOR FERTILITY IN THE VARIOUS BREEDING SEASONS AVERAGED OVER THE TWO CYCLES OF ACCELERATED LAMBING

Breed of Ram[a]	n	Winter	n	Fall	n	Late-Spring	n	Mean Over Season
HH	107	95.1±2.7	55	90.9±3.8	78	39.0±5.8	240	75.0±2.3
SS	109	90.8±2.3	57	86.5±2.8	102	42.9±4.8	315	73.4±2.0
HS	111	89.4±2.7	104	93.0±3.8	102	60.7±4.7	270	81.0±2.2
SH	102	93.2±2.8	104	93.3±2.8	80	64.1±5.8	286	83.5±2.1
Mean Over Rams	429	92.1±1.3	320	90.9±1.6	362	51.7±2.5	1111	78.2±1.1

[a]HH = purebred Hampshire ram, SS = purebred Suffolk ram, HS = crossbred Hampshire x Suffolk ram and SH = crossbred Suffolk x Hampshire ram.

n = number of ewes exposed.

TABLE XXXVI

LEAST SQUARES MEANS FOR FERTILITY OBTAINED FOR EACH BREED OF EWE COMBINATION IN EACH OF THE THREE BREEDING SEASONS UNDER ACCELERATED LAMBING

Breed of Ewe Combinations	n	Winter	n	Fall	n	Late-Spring	n	Mean Over Seasons
1/2D1/2R	93	88.6±2.9	69	92.8±3.4	78	67.0±5.7	240	82.8±2.3
1/4D3/4R	105	90.2±2.7	78	93.6±3.2	91	46.0±5.1	274	76.6±2.1
1/4F1/2D1/4R	75	92.9±3.3	54	90.7±3.9	61	50.5±6.4	190	78.0±2.5
1/4F1/4D1/2R	92	90.9±2.9	69	88.4±3.4	78	46.7±5.6	239	75.0±2.3
1/4F3/4R	64	98.9±1.8	50	86.0±4.0	54	48.2±6.8	168	77.7±2.7
Mean Over Breed Combinations	429	91.8±1.3	320	90.6±1.6	362	47.8±2.5	1111	76.8±1.1
1/4F[b]	231	93.9±1.8	173	88.4±2.2	193	48.5±3.4	597	76.9±1.5

[a]F = Finnsheep, D = Dorset and R = Rambouillet.

[b]Average over the three 1/4F groups.

n = number of ewes exposed.

TABLE XXXVII

BREED OF EWE COMBINATION BY BREED OF RAM LEAST SQUARES MEANS FOR FERTILITY IN WINTER, FALL AND LATE-SPRING BREEDING SEASONS UNDER ACCELERATED LAMBING

Breeding Season	Breed of Ram[b]			
	HH	SS	HS	SH
Winter				
1/2D1/2R[a]	96.2	88.5	78.8	90.8
1/4D3/4R	88.3	87.5	89.0	96.2
1/4F1/2D1/4R	94.4	90.9	91.7	94.4
1/4F1/4D1/2R	96.4	87.1	91.9	84.3
1/4F3/4R	100.0	100.0	95.5	100.0
Fall				
1/2D1/2R	100.0	82.6	91.7	100.0
1/2D3/4R	100.0	91.7	92.9	92.3
1/4F1/2D1/4R	100.0	94.1	88.9	83.3
1/4F1/2D1/4R	63.6	91.3	92.3	95.5
1/4F3/4R	87.5	70.6	100.0	93.8
Late-Spring				
1/2D1/2R	43.6	65.9	75.2	83.3
1/4D3/4R	36.5	38.5	46.1	62.6
1/4F1/2D1/4R	37.5	50.8	66.3	47.5
1/4F1/4D1/2R	52.5	33.3	42.7	58.3
1/4F3/4R	25.0	25.9	73.2	68.8

[a]F = Finnsheep, D = Dorset and R = Rambouillet.

[b]HH = purebred Hampshire ram, SS = purebred Suffolk ram, HS = crossbred Hampshire x Suffolk ram and SH = crossbred Suffolk x Hampshire ram.

TABLE XXXVIII

BREED OF EWE COMBINATION LEAST SQUARES MEANS FOR PROLIFICACY IN WINTER, FALL AND LATE-SPRING BREEDING SEASONS UNDER ACCELERATED LMABING

Breed of Ewe Combinations[a]	n	Winter	n	Fall	n	Late-Spring	n	Mean Over Seasons
1/2D1/2R	83	1.65±.06	64	1.77±.08	50	1.25±.08	197	1.56±.04
1/4D3/4R	95	1.46±.05	73	1.63±.07	40	1.40±.08	208	1.50±.04
1/4F1/2D1/4R	70	1.78±.06	49	1.76±.09	28	1.32±.10	147	1.62±.05
1/4F1/4D1/2R	83	1.83±.06	61	1.87±.08	32	1.38±.09	176	1.69±.05
1/4F3/4R	63	1.61±.07	43	1.98±.09	23	1.42±.10	129	1.67±.05
Mean Over Breed Combinations	394	1.67±.03	290	1.80±.04	173	1.35±.04	857	1.61±.02
1/4F[b]	216	1.74±.03	153	1.87±.05	83	1.37±.06	452	1.66±.03

[a]F = Finnsheep, D = Dorset and R = Rambouillet.

[b]Average over the three 1/4F groups.

n = number of ewes lambing.

TABLE XXXIX

BREED OF EWE COMBINATION LEAST SQUARES MEANS FOR NUMBER OF LAMBS BORN PER EWE EXPOSED IN THREE BREEDING SEASONS UNDER ACCELERATED LAMBING

Breed of Ewe Combinations[a]	Breeding Season								Mean Over Seasons
	n	Winter	n	Fall	n	Late-Spring	n		
1/2D1/2R	93	1.46±.07	69	1.64±.09	78	.84±.09	240		1.31±.05
1/4D3/4R	105	1.32±.07	78	1.53±.09	91	.66±.08	274		1.17±.05
1/4F1/2D1/4R	75	1.64±.08	54	1.59±.11	61	.64±.10	190		1.29±.06
1/4F1/4D1/2R	92	1.65±.07	69	1.65±.09	78	.63±.09	239		1.31±.05
1/4F3/4R	64	1.59±.09	50	1.70±.11	54	.67±.11	168		1.32±.06
Mean Over Breed Combinations	429	1.53±.03	320	1.62±.04	362	.69±.04	1111		1.28±.02
1/4F[b]	231	1.63±.04	173	1.65±.06	193	.65±.05	597		1.31±.03

[a]F = Finnsheep, D = Dorset and R = Rambouillet.

[b]Average over the three 1/4F groups.

n = number of ewes exposed.

TABLE XL

ANALYSIS OF VARIANCE FOR LAMBING TO CONCEPTION INTERVAL

Source of Variation	d.f.	Mean Square
Breed of Ewe Combination (BOE)	4	150.5163
Breed of Ram (BOR)	3	140.9766
Season	2	27993.3950**
Cycle	1	532.0963
Season x Cycle	2	340.5009*
Season x BOR	6	300.5135
Lambing Date[a]	1	63730.8045**
Season x Cycle x BOE x BOR	53	153.0100
Residual	588	113.4930

*Significant at $P < .05$.

**Significant at $P < .01$.

[a]Regression coefficient of interval on lambing date = $-.96 \pm .04$.

VITA

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